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THE JOURNAL OF THE SOCIETY OF AUTOMOTIVE ENGINEERS

APRIL 1924

SOCIETY OF AUTOMOTIVE ENGINEERS INC.
29 WEST 39TH STREET NEW YORK

HOW DO *YOU* VOTE?

GENERALLY it takes a long time to get recognition on something as radical as Stabilation.

In attempting to control spring rebound it has been custom for years to check the rebound at the tail-end of the movement—after the movement has gotton viciously under way. First we had the hanging type of jump strap and later, many forms of the wind-up type.

Stabilation has about-faced and gone in another direction. Stabilation is accomplished, not by a tail-end *stopping* of the rebound movement, but by the application of a brake or drag *throughout* the movement,—a drag which is heavy at the *start* of the movement, when the spring is heavily compressed, and which tapers off as the spring returns to its normal state. With Stabilation therefore it isn't a case of *stopping* a vicious movement, it's a case of *not permitting* viciousness.

Jump-strapping and Stabilation are thus precisely opposite in both principle and effect. And the logic and correctness of Stabilation has been proved beyond question by the almost instant recognition it has received.

JOHN WARREN WATSON COMPANY
Twenty-fourth and Locust Streets
PHILADELPHIA

WATSON
STABILATORS

Change the Whole Nature of Your Car

THE JOURNAL OF THE SOCIETY OF AUTOMOTIVE ENGINEERS

Vol. XIV April, 1924 No. 4

Chronicle and Comment

National Automotive Service Convention

THE attention of the members is called to the National Automotive Service Convention and Automotive Maintenance Equipment Show that will be held in Detroit, May 19 to 23, under the auspices of the National Automobile Chamber of Commerce in cooperation with the Society of Automotive Engineers, the Motor & Accessory Manufacturers' Association, the National Automobile Dealers' Association, the Automotive Equipment Association and Service Equipment Associates. The members of the cooperating associations and of dealer, trade and service associations may attend and take part in these events. Members of the Society can secure credentials upon application at its office in New York City in person or by letter. Other information, including the details of a very interesting program of papers, will be sent the members this month. In general, the discussion will relate to better-trained personnel, business policies and methods and adequate equipment. At the Show automotive maintenance equipment will be demonstrated.

The Convention and the Show will be held in the General Motors Building, Detroit. During the same week the World Motor-Transport Congress, conducted by the Foreign Trade Committee of the National Automobile Chamber of Commerce, will be in progress at the Hotel Statler, Detroit.

Research a Live Issue

CERTAINLY no work is more intimately associated with the sound progress of industry than the thorough and systematic study of basic practical problems. The broad possibilities of this type of activity in the automotive field become increasingly apparent as the Society's research interests progress. In fact, the problems of vital concern are so many as to render extremely difficult the choice of the few that are best suited to our consideration.

The direction of the Society's research activities during the year 1924 has been placed in the hands of a very competent committee of leading engineers who have already formulated plans for prosecuting a program of important work. The major projects of this program are outlined briefly on p. 381 of this issue. The personnel of the committee together with research matters of interest to our members is also given.

New Standards Issued

THE February issue of data sheets for the S.A.E. HANDBOOK contains the new and revised standards approved by the Standards Committee at the Annual Meeting in Detroit and confirmed by letter-ballot of the voting members on March 25. This issue, which will be mailed early this month, brings the total number of Handbook pages to 572.

Two new Sections are included in this issue of the data sheets: Section L, Body Standards and Recommended Practices; and Section M, General Standards and Recommended Practices. Section K is to be limited to nomenclature and tests.

Traffic Signals

THE function of the Traffic Planning and Safety Committee of the National Automobile Chamber of Commerce is to study the problems of traffic efficiency and safety, to advocate constructive improvements in the management of motor transportation, to point out its relationship in the development of cities and to lend its efforts toward the reduction of automobile accidents on streets and highways. The American Automobile Association, with which the National Motorists' Association was combined recently under the name New American Automobile Association, is planning to have a special study made in connection with bringing about greater uniformity in automobile and street signal-systems. Comment has been made repeatedly on the variation in practice so far as conditions through the Country are concerned, the question being asked particularly why the system used in New York City is different from that in effect in other cities.

John A. Harriss, special deputy police commissioner of New York City, has given the Society the following information with relation to proposed standard color-codes for automobile traffic signals:

> In New York City, stanchions used to indicate safety zones, isles of safety, etc., are painted in alternate stripes of black and white. Warning signs, direction signs, safety-zone signs, school street signs, congested-

street signs, one-way street signs, etc., are painted white with black lettering.

Stanchions placed in the streets in the night-time are marked with red lanterns, and where automatic lamps are used to indicate danger-points a red flash is shown therefrom.

Signal lights to regulate and control the movement of traffic, these being displayed from traffic-towers, are

Yellow Light—North and south traffic proceeds
Red Light—All traffic halts so as to clear intersections
Green Light—East and west traffic proceeds

Commissioner Harriss feels that, while no definite standard signal-code is followed generally, the practice described above, which is used in various communities, is very satisfactory and efficient for the particular purposes it is intended to cover.

1924 Roster

THE 1924 Roster is being mailed to the 2400 members who ordered copies. As heretofore, the main divisions of this printed list of the membership of the Society are the alphabetical register of members; the list of companies, with names of members associated therewith; and the register of members arranged according to their residence. In addition, members connected with the Army, the Navy and United States Government bureaus are listed separately. The book contains also uptodate lists of the officers, committeemen and representatives of the Society and of officers of the Sections nominated for service during the coming season. A new feature is the inclusion of a notation of the year in which each member of the Society was elected. Among the miscellaneous bits of information given is a tabulation of the number of members residing in the various States of this Country. Nearly 4400 members are located in 11 States. In numerical order these are

New York	900
Michigan	829
Ohio	655
Illinois	478
Pennsylvania	350
Indiana	270
Massachusetts	212
New Jersey	212
California	194
Wisconsin	151
Connecticut	128
Total for 11 States	4,379

The other members residing in this Country are located in 33 other States. In addition, 201 Affiliate Member Representatives and 237 Enrolled Students resident in this Country and abroad are on the rolls of the Society. Four hundred and forty-three members have their places of business outside of this Country. The total number on the rolls of the Society as of March 1, 1924, which is the date for which all of the figures are given above, is 5444.

Council Action on Sections Matters

AT the March meeting of the Council Past-President Bachman, chairman of the Special Committee on Society and Sections Organization, presented the report of that Committee which related to points as to policy and procedure with regard to Sections that had been discussed generally for several months. The other members of this Special Committee were: J. H. Hunt, chairman of the Sections Committee of the Society; H. W. Slauson, past-chairman and present member of the Sections Committee, and past-chairman of the Metropolitan Section; John Younger, vice-chairman of the Sections Committee and chairman of the Cleveland Section; and T. J. Litle, Jr., chairman of the Detroit Section. Having completed the work for which it was formed, the Committee was discontinued by the Council.

The report of the Committee was accepted by the Council. A statement of the report of the Committee is given hereinbelow. It is undersood that the Constitution Committee and the Sections Committee of the Society will take further action by way of initiating such amendment to the Constitution of the Society and amendment and change in the Constitution and procedure of the Sections as are necessary or advisable to put into effect the policies defined by the Special Committee and accepted by the Council.

Section Associate

The report of the Committee as accepted by the Council on the matter of authorizing the Sections to enroll as Associates non-members of the Society, was that

> The Committee is opposed to any form of Section membership to which non-members of the Society shall be eligible.

Admission Fee for Non-Section Members

The Committee passed the following resolution:

> *Resolved*, that the Sections be privileged at their option to charge an admission fee to non-Section members for individual meetings, such fee to carry with it only the privilege of attendance; the amount of the fee to be left optional with the Section.
>
> By a "non-Section member" is meant either a member of the Society who is not a member of any Section or an individual who is not a member of the Society. A member of one Section should be accorded the privilege of attending meetings of any other Section as a visitor.

The purpose of the Committee was to foster the value of membership in the Sections. Section members pay annual dues of $5 per year. It is felt that an unjust condition is created by the free attendance of non-Section members.

Eligibility of Society Members to Section Membership

The following resolution, passed by the Special Committee and accepted by the Council, defines the opinion as to the proper basis for eligibility of Society members to Section membership in general:

> A member, meaning an individual member of any grade in the Society now eligible for Section membership under the Standard Section Constitution, should in the opinion of the Committee be eligible to join only one Section, and that Section to be the one nearest his residence or nearest his place of business, as he may elect.

Continuity of Office-Holding in Section Governing-Boards

The Committee passed a resolution, which was adopted by the Council, indicating its opinion that the Governing Board of a Section should consist of a Chairman, a Vice-Chairman, a Secretary and a Treasurer, each to be elected and to hold office for 1 year, two Governors, one of whom shall be elected each year for 2 years, the Chairman who last held office, as Past-Chairman, and the Chairmen of the following standing committees: Program, Membership and Publicity; the last named three

Chairmen to be appointed by the Chairman of the Section.

Under the present Standard By-Laws of the Sections, the Governing Committee of a Section consists of the Chairman, the Vice-Chairman, the Secretary, the Treasurer, the Chairman who last held office, and the Chairmen of the standing committees of the Section. The Chairmen of the standing committees are appointed each year by the Chairman of the Section.

Administrative Year of Sections

The Special Committee recommended that the administrative year of the Sections be changed to begin on July 1 instead of on May 1. The purpose in this connection is to change the present condition so that the administrative year of the Sections shall be coterminous with the season so far as professional meetings are concerned. It is felt that the first professional meeting of a given administrative year should be that held after July 1. In other words, according to the present system, the first professional meeting of the administrative year is frequently held in May. This does not allow proper time for making plans for this meeting. The Council accepted the recommendation of the Special Committee as to this change.

Collection of Section Dues

A new policy with regard to the manner of collecting Section dues is contemplated. According to present and past practice, the Sections have collected the dues of their members. The Council accepted the view of the Special Committee that the office of the Society should bill the members on a form permitting them to pay their Section dues at the same time they pay Society dues. The details of the procedure are to be worked out.

Automatic Section Membership of Society Members

The Special Committee and the Council went on record as being opposed as a matter of principle to automatic Section membership of Society members, whether this is accompanied by an increase in Society dues or not.

Raising of National Dues

Since the Committee and in turn the Council went on record as opposed to automatic Section membership, it is felt that there is no occasion for increasing National dues at this time.

Section Dues

The plan recommended of charging admission fees to non-members attending Section meetings is too recent to permit of estimating the probable income from this source or the effect on Section income in general. Full information regarding operating costs of Sections is desired, and it was therefore recommended by the Special Committee that the question of possible revision of the amount of Section dues should be studied further. The Council accepted the Committee's view of this matter.

Sections Committee

The Special Committee expressed the opinion, which was received favorably by the Council, that the Constitution of the Society be revised to provide that the Sections Committee of the Society shall consist of one member of the Society to be elected from and by each Section each year; and three members of the Society who shall be appointed by the President of the Society; and that the President shall name the Chairman of the Committee.

With this change in effect, the Sections Committee would be named and organized in a manner similar to that now provided for by the Constitution of the Society in the case of its regular Nominating Committee.

The Present Status

With respect to the action in general of the Council as set forth above, the members have been afforded an opportunity to consider the various opinions that have been expressed by members, as reflected in articles in recent issues of The Journal. A number of members have favored the automatic or "adjusted" Section membership. The Council feels, however, that to put this into effect would be against the best interests of the Society and also that, inasmuch as it is believed that the sentiment in favor of automatic Section membership was based largely upon strong objection to the attendance at Section meetings of those who did not pay dues thereto, the sanctioning of charging admission fees to non-members of Sections will cure to a considerable extent at least the situation that has been objected to. In addition, it is considered that it will meet the demand that was voiced for the reauthorization of enrolling Section Associates, as under the plan that has been accepted by the Council suitable fees of admission to single meetings can be charged. The Council does not see its way clear to inaugurating the policy of requiring members to pay fees directly to a Section if they do not want to attend its meetings.

So far as the Sections themselves are concerned, the Special Committee and the Council have proceeded with the basic idea in mind that the value of work in a Section depends upon its initiative effort. Local management of the Sections and friendly rivalry between them are desired. To create and maintain adequate interest in a Section, it is necessary that it hold meetings of sufficient interest to attract a good representative attendance. The privileges and benefits afforded by Sections are much more than commensurate with the amount of Section dues. Section meetings give the opportunity not only to acquire information on professional matters but to extend acquaintanceship with those whom it is most desirable that the average member should know. Owing to conditions surrounding their work, the Section meetings are the only type of Society meeting that many members can attend. No Society member can secure a large part of the benefit of a Section meeting by reading reports about it. Each member owes it above all to himself to participate in the activities of the Section that has headquarters in his territory, to the greatest extent that it is feasible for him to do so. The view that the payment of $5 to a Section absolves him from this or any related obligation is short-sighted.

Finance

The 11 Sections of the Society that have been established for some time had in their treasuries on March 1 last on the average somewhat in excess of $900, these monies having been accumulated by receipt of appropriations from the treasury of the Society and by collection of Section membership dues.

The Constitution Committee and the Sections Committee of the Society now have under consideration the further steps involved in the policy that has been outlined as stated hereinbefore. John H. Hunt, chairman of the latter Committee, is conferring with its members with regard to the advisability of modifying the formula according to which the Society has recently been ap-

(*Concluded on p.* 443)

MEETINGS OF THE SOCIETY

SUMMER MEETING PLANS PROGRESS

Arrangements for Other National Meetings Announced by Meetings Committee

Air-cleaners, oil-filters, crankcase-oil dilution, riding-quality and new types of transmissions will be the subjects taken up in the technical sessions at the Summer Meeting. As announced in the March issue of THE JOURNAL, this popular national convention will be held on the Atlantic seashore at Spring Lake, N. J., June 24 to 27. The general plan of the meeting as tentatively arranged is as follows:

TUESDAY, JUNE 24

Morning—Registration and assignment to rooms
Afternoon—Session on Riding-Quality
Evening—Semi-Annual Business Meeting, followed by entertainment

WEDNESDAY, JUNE 25

Morning—Session on Oil Dilution
Afternoon—Recreation; starting of all tournaments
Evening—Session on Oil Dilution

THURSDAY, JUNE 26

Morning—Standards Committee Meeting
Afternoon—Annual Field Day
Evening—Session on Air-Cleaners followed by Grand Ball

FRIDAY, JUNE 27

Morning—Session on Transmissions
Afternoon—Swimming events; conclusion of all tournaments
Evening—Close of meeting; departure of special trains

While a number of excellent papers have been procured for the technical sessions, the programs are still tentative and their announcement will be delayed until about May 1. Meantime, members hoping for a place on any program should write the New York City office post-haste to avoid disappointment.

SOCIETY WILL NOT SPONSOR TOOL EXHIBIT

An exhibition of production equipment will not be held under the Society's auspices during the Production Meeting in Detroit, next October. The suggestion that we sponsor and manage such a show has come from many members, but the Council decided against it after a study of the situation. This action is not to be interpreted as a reflection of disfavor toward the exhibition as such, but merely as the judgment of the Council that the Society lacks the personnel and time to enter the exhibition field. Efforts will be made to encourage the staging of the proposed show under other auspices and, if successful, the Society will cooperate in every way to coordinate its production session with the exhibition dates. The Production Meeting is scheduled to be held in the General Motors Building, Detroit, Oct. 22 to 24.

With the announcement of the Automobile Show dates by the National Automobile Chamber of Commerce it is possible to set definitely the dates of several national meetings of the Society. These are as follows:

Motorboat Meeting—New York City—Jan. 7, 1925
Annual Dinner—New York City—Jan. 8, 1925
Annual Meeting—Detroit—Jan. 20 to 23, 1925
The Carnival—Detroit—Jan. 21, 1925

TRACTOR MEETING THIS MONTH

National Gathering in Chicago on April 24 Devoted to Farm and Industrial Uses

Members interested in the future of the tractor industry will do well to attend the national Tractor Meeting of the Society in Chicago on Thursday, April 24. Not only will they be privileged to hear three excellent talks, but they will profit by the frank and open discussion of what can be done in an engineering way to extend the use of tractors. A few years ago it was the general impression among engineers that agriculture presented the most fertile field for tractor application. Now this opinion is doubted in many quarters and rightly so. We hear of tractors building highways, hauling heavily loaded trailers, assisting in drainage projects, pulling lines of dump-cars on rails, handling building material and no end of other applications.

Then there is the universal demand upon the farmer's part for an agricultural tractor that will more nearly displace his horses. Many engineers have racked their brains trying to answer this demand. Has it been done? Let us get together and see what progress has been made. Furthermore, let us talk over the advisable steps to take in the future.

This meeting is not advanced as an opportunity to clear the economic skies of the tractor industry, but it will help. Certain it is that those who participate in the discussion of the papers will benefit greatly from the experience. Engineering problems are not solved expeditiously within the confines of one's own office. Every new and impartial view contributes something toward their solution. If the Chicago Tractor Meeting stimulates further study of tractor applications and the development of tractors better suited to the work demanded of them, the meeting will have accomplished its major purpose.

AUDITORIUM HOTEL IS MEETING HEADQUARTERS

Two technical sessions will be held, one in the morning starting at 10 o'clock and the other starting at 2:30 p. m. An informal luncheon will be served during the noon period. Meetings and luncheon will be located at the Auditorium Hotel. All members of the Society are welcome and may bring guests on this occasion.

O. B. Zimmerman, research engineer with the International Harvester Co., will read the paper on General Purpose Tractors. It is generally known that the Harvester engineers have devoted considerable study to making farm tractors more versatile. It is a rare privilege for our members to hear some of the conclusions of that study.

George D. Babcock, manufacturing executive of the Holt Mfg. Co., will present the talk on Industrial Applications of the Tractor. Holt tractors have been used successfully in widely diversified fields and this talk will not only describe

these applications but will also illustrate them with motion pictures.

The Tractor Luncheon will be addressed by Cyrus H. McCormick, Jr., who will speak on the Commercial Importance of Engineering.

BALLOON-TIRE REPAIR MAY BE DIFFICULT

Minneapolis Section Speaker Implies New Vulcanizing Methods Will Be Needed

Lessened servicing requirements for balloon tires, claims that they will require fewer repairs on account of less liability to injury, seem to be offset in some degree by the need of larger and more expensive equipment made necessary by the increased size of the tire. It does not seem possible that major repairs can be made on these tires by the methods employed in the past. This belief was expressed by L. O. Grange, of the Northwestern Tire Co., Minneapolis, in presenting his paper at the Section Meeting held on March 5. He covered in detail the subjects of tire carcass, tread, tubes, tire sizes, rims, factors that affect car-driving ability and applications of these tires to cars, bringing out new and interesting attributes of the balloon tire.

Regarding major repairs, a considerable amount of new material is added to the tire by the unusual methods, the result being that the tire becomes appreciably stiffer in the repaired section and offers considerably more resistance to flexure than does the remainder of the tire. This stiffening will tend to raise the tire when rolling over the repaired part, causing a pronounced hinging action at each end of the repair. When it is considered that a tire revolves approximately 8,000,000 times to cover a normal mileage, it seems impossible that these repairs can give service, especially with the greater percentage of deflation recommended.

Close attention to the maintenance of proper inflation-pressure is requisite to avoid damage from under-inflation. A high-pressure tire inflated to an 80-lb. per sq. in. pressure would not be injured seriously if this pressure became reduced to 75 lb. per sq. in.; but a drop in pressure from 25 to 20 lb. per sq. in. for a balloon tire is a 20-per cent reduction, being great enough to cause serious damage to the tire. For comparison, a 20-per cent reduction of high-pressure-tire inflation-pressure from 80 lb. per sq. in. would be to 64 lb.

Mr. Grange said that it does not seem logical to expect the balloon tire to displace the high-pressure tire for passenger-car use until its advantages have been proved definitely at the hands of the public. For this reason, statements relative to the performance of the balloon tire should be taken as a prediction of its possibilities, rather than a record of its service. In reference to tubes, Mr. Grange mentioned that those for the larger sizes of tire will be made on a circular mandrel that will allow the tube to lie in the tire in the same shape as that in which it was cured.

Tests of balloon tires indicate that they will operate at a greatly reduced temperature from that of the standard tire, and this is particularly noticeable at the higher speeds. The ability of the balloon tire to operate at lower temperature is due to the use of fewer plies in the carcass and the increased size that enables it to radiate heat quickly.

In the opinion of many dealers with whom Mr. Grange has talked, the balloon tire is undoubtedly here to stay but is now in a stage of early development that should have been carried through at the factory and that now must be carried through by the dealer. One dealer said that the balloon tire should be introduced as equipment on a new car only; that is, the car should be designed for the tire. Now, balloon tires are applied to various makes of car and trouble due to improper clearances and the like is experienced. In some cases, people object to the instability at high speed. This may be due to the narrow rims that have been used. Some say the rim width should be increased to provide greater stability. What the result will be is a matter of conjecture and will not be settled for about a year. Starting

NATIONAL MEETINGS CALENDAR

TRACTOR MEETING
Chicago—April 24

SUMMER MEETING
Spring Lake, N. J.—June 24-27

AUTOMOTIVE TRANSPORTATION MEETING
New York City—Sept. 24-25

AERONAUTIC MEETING
Dayton—Oct. 3

PRODUCTION MEETING
Detroit—Oct. 22-24

SERVICE ENGINEERING MEETING
Cleveland—Nov. 18-19

MOTORBOAT MEETING
New York City—Jan. 7, 1925

ANNUAL DINNER
New York City—Jan. 8, 1925

ANNUAL MEETING
Detroit—Jan. 20-23, 1925

THE CARNIVAL
Detroit—Jan. 21, 1925

with 4 sizes for these tires, the total is now 23 and, in Mr. Grange's opinion, the tire dealers are in a quandary as to what the ultimate number of sizes will be. He believes also that the engineer must consider very carefully the springing of a car, in conjunction with the use of balloon tires; the thing to avoid is an up-and-down swaying-action, rather than a bouncing action.

Jack Harrison said in the discussion, regarding a 6000-mile test of a new twin-six car equipped with balloon tires and operated by a taxicab company in Chicago, that the vehicle was run with no oil on the springs and had no noticeable rattle, even when traveling over cobblestones. The tires were in good condition after this test. Then the car was equipped with 35 x 5-in. high-pressure tires and tested; the noise was excessive, so much so that a person riding in it could scarcely "hear himself think."

Asked whether he believed the six-ply balloon-tire would prove to be the "happy medium," Mr. Grange said it seemed probable that six plies would be used eventually. The six-ply carcass will make the tire more stable, and some of the car builders believe this to be very desirable. Regarding prices, he said that the increased size of a balloon tire necessitates a larger mold to cure it and so would increase the cost of production. The weight of the tire and the actual amount of material in it are estimated to be about the same as for the tire it replaces.

Concerning the number of plies used in the balloon tires with which the taxicabs of a large operating company in Chicago are equipped, Mr. Grange said this company has tested two, four and six-ply tires, and that the four-ply tire has given the best results. He believes that the public will necessarily constitute the testing medium for a great amount of experimental work on the balloon tire and said that some tire dealers think it is on the market about a year too early.

HEAD-LAMP EFFECTIVENESS

Prime Requisites of Road Illumination and Suggested Methods of Improvement

R. E. Carlson

Head-Lamp adjustment, head-lamp devices and head-lamp glare are subjects upon which much attention has been directed in the last several months, but their importance was emphasized again by the presentation of additional data to the New England Section by R. E. Carlson, at the meeting held March 11, 1924, at Boston, and by the snappy discussion that followed. A test was conducted by the Bureau of Standards in the City of Washington on the road-lighting equipment of some 400 cars built by 56 motor-car companies, and the results were summarized by Mr. Carlson, who is a mechanical engineer for the Bureau. He said that 36 per cent of the cars tested had lenses that were twisted in the lamp housing, 73 per cent of the lamps were out of focus and 54 per cent of the cars had glaring head-lamps.

Of the devices for spreading the light and for tilting, 30 such devices have been accepted by the Conference of Automobile Administrators. Mr. Carlson believes tilting the beam down by moving a controlling lever to be better practice than dimming the light; also, that material progress will be made in the solution of the problem if proper head-lamp equipment is provided by the builders when the cars are first sent out.

The meeting was preceded by a dinner, and both were well attended in spite of the severe storm that was raging. A number of prominent representatives of the industry and several State officials participated in the discussion, contributing valuable suggestions regarding head-lamp construction and inspection and the enforcement of regulations.

For the benefit of those especially interested, a brief bibliographical list of the most recent data on these subjects is appended, the references being to issues of THE JOURNAL.

Importance of Better Automobile Head-Lamps and Proper Adjustment, by R. N. Falge and W. C. Brown, July, 1923, p. 25; October, 1923, p. 350; January, 1924, p. 31

Automobile Head-Lamp Regulation, by James J. Shanley, September, 1923, p. 249

Illumination Diagrams for Showing Head-Lighting Device Performance, by F. H. Ford, October, 1923, p. 333

The Automobile Head-Lamp Situation, summarizing a paper by R. E. Carlson, December, 1923, p. 526

TRAFFIC-CONTROL PROBLEMS

Police Regulation Alone Is Insufficient. All Means Must Be Utilized

Major Mark L. Ireland, U. S. A.

Street congestion and remedies for traffic difficulties were considered in their many phases at the Cleveland Section meeting held on March 17. In presenting the subject of city-highway traffic-control from a military point of view and comparing military and civilian methods, Major Mark L. Ireland, U. S. A., said that corporate business methods applied to city traffic-control would reduce its cost and conserve life. Lack of unity causes almost exclusive reliance on police control as distinguished from the many other means for controlling traffic.

Military traffic-control is a function exercised by the higher commanders to secure an approach to the greatest practicable passenger, or ton-mile-hour, capacity of roads and terminals. It cannot be exercised by lower commanders because they are unable to make provision for: (*a*) bringing new independent formations into the battle area; (*b*) coordination of highway, waterway and railway traffic; (*c*) uniformity of traffic-control regulations; (*d*) unification of authority over single routes and (*e*) deciding priorities of traffic over congested routes.

Civilian traffic-control is a regulative function over the public highway, at present not exercised by the highest civil officers but by the municipal or communal police authorities. The cardinal principle, the greatest good for the greatest number, is the same as for military traffic control.

Commercial transportation is still a long way from accomplishing the economies incident to operation in large groups. It organizes for dispatching, garaging, solicitation of business and maintenance, but it disintegrates for operation.

There are many roots to the difficulty of civilian traffic control; one is that we have been so unprepared and un-

ready for the transportation development since the first automobile of the late '90s that in many cases we have thrust the traffic into natural and inadequate channels on the one hand and, on the other hand, when we have improved or created new channels of traffic, we have almost invariably drained into them traffic that has no legitimate reason for being there. Without variation, the result has been overload, congestion, economic loss and accidents. The principle that has been violated is: Keep cargo and passengers away from the places where they do not need to be.

Major Ireland advocated by-passing congested centers for through traffic, sifting general traffic into the three divisions, through traffic, traffic of origin or destination and purely local traffic, with plans for the separate routing and handling of each. Numerous lantern slides illustrative of traffic problems and their solution were exhibited.

Figs. 1 and 2 are of special interest with reference to city planning. Fig. 1 shows a conventional method of subdividing a triangular area into blocks 200 x 700 ft. by streets 60 and 80 ft. wide that results in acute intersections with the diagonal bounding street. Fig. 2 shows a more desirable subdivision of the same triangular area by streets 40 and 50 ft. wide, with better junctions with the diagonal bounding street. In the division shown in Fig. 1, eight street intersections are at an acute angle and the probable number of traffic policemen required is 16; for the division as in Fig. 2, the acute intersections number only four and but 12 traffic policemen probably would be needed.

Major Ireland pointed out that the principal cause of traffic difficulties in towns having more than 20,000 inhabitants is plainly of misplaced traffic, and that exclusive police control of traffic is merely a palliative measure, not a corrective one. He advocated the operation of traffic according to definite schedules that can be made fair and productive of dividends. Provision also should be made, in his opinion, for unified traffic control over single routes, in place of having each separate hamlet more or less supreme and sensitively independent with regard to traffic regulation. He said also that failure to fix responsibility for satisfactory traffic regulation on some supreme authority is a serious defect in the present method.

Herbert Buckman, manager of the Cleveland Automobile Manufacturers & Dealers Association, read its second annual report. Among its important features was the statement that congested traffic conditions daily become more a matter of dollars and cents to the automobile dealers of the community. It says that congestion as a sales resistant has not yet become acute in Cleveland, but that such a situation will develop before natural growth would bring it unless the situation is watched continuously. The report points

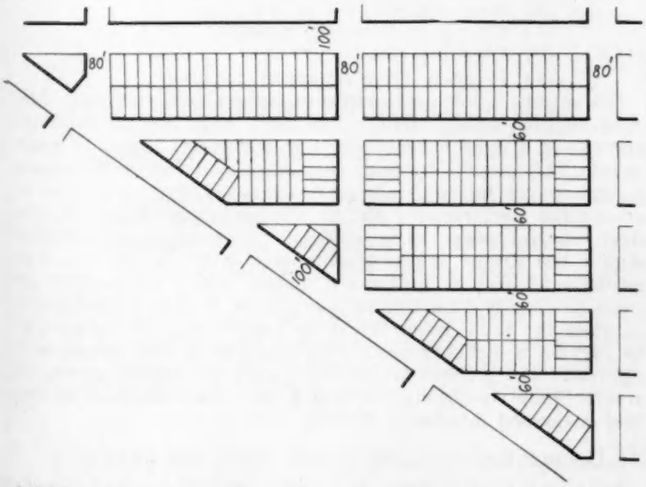


FIG. 1—CONVENTIONAL METHOD OF SUBDIVIDING A TRIANGULAR AREA In This Arrangement Streets 60 and 80 Ft. Wide Are Used To Produce Rectangular Blocks Measuring 200 x 700 Ft., the Result Being That These Streets Intersect the Diagonal Bounding Street at Acute Angles. Another Serious Objection to This Scheme Is the 40 x 100-Ft. Building Plots

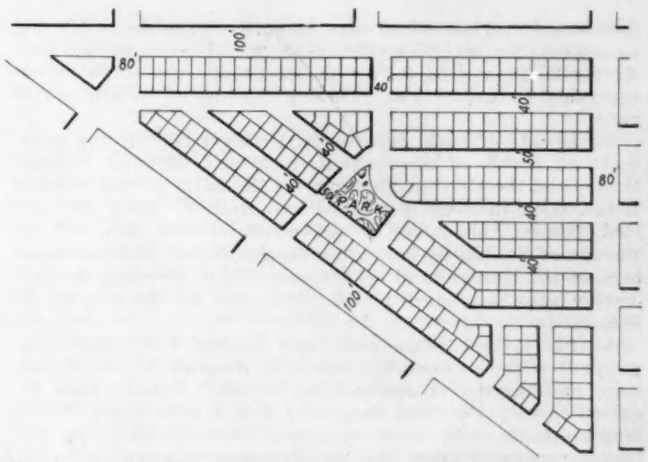


FIG. 2—AN ALTERNATIVE SUBDIVISION OF THE AREA SHOWN IN FIG. 1 Here Streets 40 and 50 Ft. Wide Are Used. The Streets in This Arrangement Intersect the Diagonal Bounding Street Practically at Right Angles, Building Plots 50 Ft. and 60 Ft. Deep Are Provided and Space Is Available for a Small Park

out that the traffic problem of the future is more a matter of engineering and less a matter of police restriction than has been realized, and that Cleveland must begin to think of traffic control in engineering terms. In answer to its question "What can be done toward improvement," it says that the automobile dealers' group can always work effectively with and through other organizations whose legislative activities have a broader scope, giving as an instance the recent completion of the most constructive survey and report ever submitted of local traffic conditions and needs, made by the Cleveland Association of Building Owners & Managers.

L. A. Schulke, secretary of the latter association, said in part that the United States should attack its traffic problem in a national way and that a national clearing house for all ideas on traffic control should be established. For Cleveland, he said the greatest immediate need is for the unification of effort and a central authority, in addition to having an organization to study traffic problems.

BRAKE PERFORMANCE IMPROVED

Washington Section and Bureau of Standards Give Demonstration of Better Braking

Braking enthusiasts were given an opportunity to watch their favorite brakes perform at the demonstration arranged in the City of Washington on March 7 by the Society's local section in cooperation with the Bureau of Standards. Fourteen stock cars of different makes were entered, the majority of them having brakes on four wheels. Three of the four-wheel type and two of the two-wheel models were equipped with balloon tires.

It is stated that the average brake-performance demonstrated in these and in other recent runs is superior to that evidenced by the runs made at Spring Lake last June. This improvement may well be taken as the inevitable result of the intensive study that has been focused on the problem.

DECELERATION AND STOPPING DISTANCE

Four-wheel braked cars, 10 in number, showed deceleration rates on dry asphalt pavement which averaged 20.9 ft. per sec. per sec. as compared with an average of 11.1 ft. per sec. per sec. for four cars equipped with two-wheel brakes. On the same pavement thoroughly washed and wetted, the rates averaged 17.5 and 8.2 ft. per sec. per sec. for the respective types. Stopping distances from an initial speed of 20 m.p.h. as computed from the above data would average on the dry pavement approximately 20 ft. and 39 ft. for the

four-wheel and two-wheel cars respectively, while on the wet pavement the stopping distances would average approximately 25 ft. and 54 ft. for the respective types. With one exception no appreciable skidding was noted in any of the runs.

Three sets of runs were made, the first two on dry pavement at speeds of approximately 20 and 30 m.p.h. respectively, and the third at 25 m.p.h. on the same pavement after it had been thoroughly washed and wetted. Each car carried, besides the driver, a police official who observed the Bureau of Standards indicating decelerometer, and two members of the Bureau staff who operated the recording decelerometer also developed by W. S. James at the Bureau of Standards.

At the instant when each car reached the "stop" line painted on the pavement, a flag was dropped by the signalman, and the driver applied the brakes. The distance required to stop was then measured with a steel tape. These measurements were later compared with the stopping distances computed from the decelerometer records.

Articles concerning the Bureau of Standards instruments and the methods of brake testing have appeared in recent issues of THE JOURNAL, as follows: December, 1923, pp. 499 and 522; January, 1924, p. 80; and February, 1924, p. 236.

DRIVER'S TIME OF REACTION

An interesting feature of the demonstration was a test of the driver's time of reaction, that is, the time required for him to start applying the brakes after receiving a given signal. This was determined by two revolvers loaded with red lead and fixed upon the running-board in such a way as to fire against the pavement. A cord attached to the trigger of the first revolver extended to the passenger who gave the stop-signal by pulling the cord that released the trigger. The second revolver was so connected with the brake-pedal as to discharge at the instant when pressure was applied.

At a speed of approximately 20 m.p.h. and with the driver's foot initially upon the foot-throttle, the distance between the red-lead marks on the pavement was 9 ft. In this way the distance through which the car progressed while the driver reacted to the signal was indicated.

W. S. JAMES DISCUSSES TESTS

In the evening following the demonstration, W. S. James presented the results of the tests before the monthly gathering of the Washington Section. His paper pursued the same general lines as those referred to above which have already been given before the Society.

The results of braking effectiveness of 16 cars equipped with two-wheel brakes and selected at random showed that, with the foot-brakes only, the average distance required to stop from an initial speed of 20 m.p.h. was 53 ft. as compared with 84 ft. for the so-called emergency brakes alone.

A series of tests of the time of reaction of various drivers showed an elapsed time between the stop-signal and the beginning of the deceleration of the car that averaged 0.42 sec. for the foot-brakes and 0.51 sec. for the hand-brakes. At a speed of 30 m.p.h. the equivalent distances are 18.5 ft. and 22.5 ft. for the foot-operated and the hand-operated brakes, respectively.

Several interesting alignment charts prepared at the Bureau were shown to illustrate rapid methods of determining various factors in the braking problem.

The following cars participated in the demonstration: Buick, Cadillac, Wills Ste. Claire, Lincoln, Marmon, Oakland, Packard, Rickenbacker, Cleveland, Duesenberg, Franklin, Chrysler and Rollin. Packard was represented by two six-cylinder models equipped respectively with two-wheel and four-wheel brakes. The Lincoln, Cleveland and Franklin were the other two-wheel braked cars demonstrated. Both mechanically and hydraulically operated brakes were present.

Chairman Warrington of the Washington Section managed the demonstration, while W. S. James, chief of the automotive powerplant section, Bureau of Standards, was in charge of technical details. The latter was assisted by A. W. Herrington of the Motor Transport Corps and by Messrs. Eisinger, Kohr, Thorne, Sparrow and Von Ammon of the Bureau of Standards staff.

SECTION OFFICERS NOMINATED

At the brief business session that preceded the brake discussion the following names were announced by the nominating committee as the 1924 nominees for the offices indicated: A W. Herrington, chairman; C. H. Warrington, vice-chairman, and C. H. Young, Secretary-treasurer.

DISTRIBUTION IS FUEL-ECONOMY FACTOR

General Motors Research on Manifolds Emphasizes Importance of Good Design

H. W. ASIRE

Extensive studies of gas distribution with manifolds of sundry and divers shapes have been completed at the laboratories of the General Motors Research Corporation at Dayton. Members of the Indiana Section had the good fortune of hearing an excellent paper at their March meeting describing the test methods used and some of the surprising results of this investigation. The paper, written and presented by H. W. Asire, is printed in full on p. 387 of this issue of THE JOURNAL; hence there is no need of abstracting it here. Prepared discussion was presented at the meeting by several authorities on carburetion and this is reviewed in part herewith.

O. C. Berry, chief engineer of the Wheeler Schebler Carburetor Co., expressed the opinion that present-day carbureters fulfil their function of metering devices in a fairly efficient manner. Poor fuel-economy is chargeable to factors entirely removed from the control of the carbureter or its designer. Motorists demand certain qualities in a carbureter which may be enumerated as follows:

(1) Easy starting in any kind of weather
(2) Positive action while warming-up
(3) Positive action at low speeds
(4) Good acceleration
(5) Strong hill-climbing ability
(6) High top-speed
(7) Freedom from irregular running

To satisfy all these conditions means compromising fuel economy to some extent. The first requirement demands the use of a dash control and the carbureter engineer must accept the possibility that the average driver will misuse it and waste an appreciable quantity of fuel. To insure acceptable performance during the warming-up period, the dash control must be a complete carbureter adjustment. Again the driver must be entrusted with handling a fine adjustment and he invariably wastes fuel. Comparatively little driving is done below 15 m.p.h. so that it is customary to meet the third requirement by calibrating the carbureter to furnish a comparatively rich mixture at low speeds and approach the economical mixture ratio at speeds above 15 m.p.h. This compromise effects a negligible increase in the fuel consumed in general driving service.

DOUBLE-RANGE CARBURETERS BEST FOR ECONOMY

It would be possible to meet acceleration requirements by setting the carbureter to provide a richer mixture than is necessary for steady running. This will provide improved acceleration quality but will result in a considerable waste of fuel. It is better to provide some means for supplying a

temporarily enriched mixture during the acceleration period. If the quality of extra fuel and the rate of delivering it are both carefully adjusted to the requirements of the manifold, very little fuel is wasted with this method. Whatever fuel is wasted can be charged to the manifold rather than the carbureter. Several designs of carbureter now on the market will fill the requirements of hill-climbing ability without an undue waste of fuel. This is accomplished by designing the carbureter to furnish a lean mixture for economy when the throttle is only partly open and a full-power mixture when it is wide open. It is true that a great many of the present-day carbureters are not designed to accomplish this result. The high top-speed requirement is met by fitting carbureters that are large and free and adjusted for full power. The double-range carbureter has the same advantage in this case as it has in hill climbing.

It is Mr. Berry's belief that freedom from loading, rolling and irregular running is more dependent upon the manifold design than carbureter characteristics. However, the responsibility for an unsatisfactory result is usually placed on the shoulders of the carbureter engineer and he is forced to develop very fine metering devices to offset discrepancies in the manifold design. Mr. Berry recommended that automotive engineers who find it impossible to use expensive double-range carbureters for cost reasons, arrange to sacrifice just a little power in adjusting a single-range carbureter and thus secure a considerable increase in fuel economy. The difference in power may be so small that an expert driver cannot sense it, yet the gain in economy may be 4 or 5 miles per gal.

Curves were presented in Mr. Berry's discussion to demonstrate that a good carbureter is an accurate metering device. When properly installed on an engine using a well-designed manifold, instruments of this type will give carburetion performance that will please even the most exacting engineer.

Factors That Increase Fuel Consumption

A number of factors that would contribute to lowering the fuel consumption of automobiles were mentioned by Mr. Berry. He recommended that some type of automatic spark-timing device be fitted, citing an example where a retarded spark resulted in a 17-per cent loss in efficiency. Dragging brakes may cause a loss of 1 or 2 miles per gal. in fuel consumption. The demand of the American driver for an active car means that most of our cars are overpowered when viewed from the angle of fuel economy. This condition will not change so long as there is an ample supply of inexpensive fuel.

Methods used in applying heat to the intake-manifold have improved greatly in the last 2 or 3 years. Some fuel installations are very well worked out, but in the great majority of cases this is far from true. In some manifolds far too much heat is used and the fuel is boiled in the carbureter jet, thereby upsetting the mixture-ratio. In other manifolds far too little heat is applied, making the proper distribution and positive acceleration hard to obtain. In some of these cold manifolds any carbureter using enough gasoline for acceleration when the throttle is not open will load badly when accelerating under normal conditions. In Mr. Berry's opinion, nearly all manifolds can stand more heat than they are now receiving. The small loss of power due to a slightly higher mixture-temperature is more than offset by smoother performance, better economy, quicker warming-up and lessened crankcase-oil dilution. Even an increase in the size of the stove for heating the air entering the carbureter is often a real help. Mr. Berry concluded his remarks by saying that the carbureter engineer would enthusiastically support anyone who encouraged the study of better intake-manifolds.

Many Hot-Spots Are Not Effective

W. B. Barnes, assistant engineer of the Wheeler-Schebler Carburetor Co., described some comparative tests of carbureters and manifolds which he had made on a small four-cylinder engine. Three types of manifold were used; first, an experimental manifold was tried without using any heat whatsoever or any hot-air stove; second, a manifold specially designed to distribute the mixture without the aid of heat; and third, a manifold that distributes a cool mixture fairly well, but that is very generously heated. The same carbureter was used on all three manifolds, but was very carefully adjusted to each manifold to give the best performance possible. The first manifold loaded badly and gave such inconsistent results that no record of them was presented by Mr. Barnes. Comparative tests of the second and third types of manifold reflected a gain in efficiency of about 15 per cent at the lighter loads in favor of the hot manifold. With the cool manifold, about 1½ miles of steady driving

Schedule of Sections Meetings

APRIL

2—Minneapolis Section—Development of a Light Racing-Car—J. L. Larson
Milwaukee Section—Future Passenger-Car—C. W. Pendock

3—Detroit Section—Chassis Lubrication—F. H. Gleason—Discussion by A. F. Masury and C. T. Myers
Indiana Section—Steering-Gears—F. F. Chandler; Anti-Glare Symposium

4—Washington Section—Accessibility, Its Effect on Maintenance Costs and Flat-Rate Charges—A. W. Herrington

8—Pennsylvania Section—Four-Wheel Brakes—John Cautley

11—Mid-West Section—The Modern Motor Rail-Car—Col. M. L. McGrew

15—New England Section—Chassis Lubrication—F. H. Gleason
Dayton Section—Radiation Characteristics of Internal-Combustion Engines—Thomas Midgley, Jr.

17—Metropolitan Section—Some Observations of a Motor-Vehicle Superintendent—J. F. Winchester
Detroit Section—Inspection—Papers by several production men

21—Cleveland Section—Radio—R. J. Nightingale

MAY

7—Milwaukee Section—Fuels—Thomas Midgley, Jr.

13—Pennsylvania Section—Motorbus Design and Operation—A. E. Hutt

at 20 m.p.h. was required to warm the engine up to the operating temperature in freezing weather. With the hot manifold, the engine was warm enough to perform satisfactorily after running ½ mile under the same conditions. Acceleration and hill-climbing performance were very satisfactory using the heated manifold. There appeared to be no tendency to aggravate detonation, even with considerable carbon in the combustion-chamber. These tests were cited by Mr. Barnes to show that more heat can be used on the intake-manifold than is now used in the majority of cars. In too many instances, the heat is either applied at the wrong place on the manifold or the heated surface is too small. In other cases, the hot-spot is located in a dead end of the exhaust-manifold or is so far away from the latter that the exhaust gases are virtually cooled before they reach the hot spot. A. W. Linkert, W. G. Wall and F. C. Mock also contributed to the discussion.

PRODUCTION TOPICS AT DETROIT

Ford Balancing and Permanent-Mold Castings Are Section Meeting Subjects

D. H. Meloche

Balancing as practiced in the production of the Ford car was described at the March 20 meeting of the Detroit Section by Thomas Clendening. The accuracy demanded by the Ford Motor Co. in its production work is not generally appreciated among engineers. Many erroneous impressions were dispelled by Mr. Clendening's statement of the Ford tolerances and methods that are comparable with practice in factories building expensive cars. For example, 15 parts of the Ford engine have machining limits of 0.0005 in. and the gages for these parts are checked every 8 hr., and in some cases every 4 hr. The assembling of engines at the branch assembly-plants was found unsatisfactory, because of the greater time required and the difficulty of securing uniform engine performance.

To reduce the vibration resulting from unbalanced reciprocating parts, the Ford pistons and connecting-rods are weighed separately and assorted in lots varying within ⅛ oz. Heavy rods are assembled with light pistons and vice versa. The assemblies are weighed and assorted into five classes, the final variation being ⅛ oz. or under in each set assembled into an engine.

Ford Crankshafts to Be Balanced Dynamically

Crankshaft, flywheel, magnets, brake-drums and transmission shaft are all balanced carefully. Crankshafts are balanced statically within close limits and are checked for straightness and for outside diameter of the flywheel flange. Preparations are now being made to balance all crankshafts dynamically. The machining limits and final inspection on the flywheel have been made more rigid and the outside diameter is now held within 0.003-in. tolerance. By reason of the more accurate measuring and weighing of the steel bars used in making flywheel-magnets, the limit in variation of the weight of a set of magnets has been reduced from 0.125 to 0.080 oz.

More uniform castings for the brake-drums and a change in the method of machining, chucking from the inside instead of the outside face, has effected proper balance of these parts. The transmission shaft is now finished by a grinding operation and this change has reduced the number of transmissions out-of-balance by 65 per cent.

Casting in Permanent Molds

Quantity production of intricate iron castings using metal molds and accomplished with unskilled labor was described in a paper on Recent Developments in Permanent-Mold Castings by D. H. Meloche of the Holley Carbureter Co. Some of the important points brought out by Mr. Meloche are outlined in the following paragraphs.

Previous to the last decade the use of metal molds was largely confined to the non-ferrous field, the early attempts showing that gray iron poured into a metal mold produced an unmachinable casting, due to the quick chilling of the casting's surface. Further, the high temperature of the molten metal quickly raised the temperature of the iron mold until the two were welded together. The new development of this practice resulted from a study of the problem of producing an intricate casting in large quantities without blowholes or porous spots and having a uniform homogeneous structure. The conditions existing in the sand mold were studied step by step and applied to the metal-mold process. The regulation of the cooling rate was found to be the key to the whole problem, and this regulation was obtained by controlling the following factors:

(1) The thickness of walls in the hollow metal mold which are approximately ½ in. thick. The molds are of ordinary gray iron, cast to shape in a metal mold
(2) A heat barrier between the molten iron and the metal mold consisting of ordinary fire clay with a heat-resisting binder. This barrier is called a "stone facing" and is from 0.010000 to 0.015625 in. thick
(3) Protection of this stone facing after each casting by a coating of lampblack, applied by means of a smoky flame
(4) The expansion of the iron when freezing by holding the parts of the mold together by powerful springs
(5) The temperature of the molds, a slight artificial cooling by a blower or a fan giving increased production
(6) Cleaning molds after each casting. This is done by air blast, not only to blow out the sand and dirt, but to insure a fresh coating of lampblack

All ranges of mixture of iron from ordinary malleable to ordinary cast iron have been successfully used. The shrinkage of the iron casting is about one-half that which would be expected when using a sand mold, probably because the iron contours itself during the expansion stage rather than during the contracting stage.

No Surface-Chilling in Metal-Mold Castings

The fracture of a metal-mold casting appears darker than that of an ordinary gray-iron casting, and shows the carbon more uniformly distributed throughout the mass. There is comparatively little combined carbon. Where the ordinary sand-mold casting shows a minute skin of chilled iron, this does not appear in the metal-mold casting. In fact, the latter casting shows the gray-iron structure extending up to the surface, due to the surface absorption of carbon from the face of the mold by the molten metal. This reaction also protects the molds by absorbing heat and thus reducing the thickness of insulating coating required.

The molds used are themselves cast in metal molds and require no machining, except on the matching ribs, and are thus very inexpensive. The equipment as used in production consists of revolving tables on which 12 sets of molds are located, one machine producing 400 castings per hr. according to the nature of the castings. A machine is operated by two or three men. The molds are preheated before the machines are started each morning to remove any moisture that might be present when the molten metal is first poured.

Permanent-Mold Castings More Homogenous

Tests of castings made by this method show an increase of approximately 30 per cent in compression strength and a slight increase in strength on transverse tests. The homogeneous structure obtained by the use of the metal molds adapts itself better to accurate machining and makes it more applicable to castings of small dimensions that are subject to many machine operations at rapid speeds. Pistons made by this method have shown less wear than sand-molded pistons. The use of unskilled labor, the reduction in maintenance cost of die-cast machines, molds, etc., and the saving in floor space all combine to make a great saving over sand-cast molding, and in addition have produced a superior product.

Discussion Raises Interesting Points

In answer to questions, Mr. Meloche stated that the scrap of rough castings was about 7 to 8 per cent as compared with 20 per cent from sand molds; and the machining scrap was also reduced from 5 or 6 per cent to about 2½ per cent. The weight of castings by the two methods was practically the same, but the control of the heat in the metal molds assures a more homogeneous structure. The life of molds used for pistons averages 10,000 castings and it has run as high as 25,000 castings. The permanent mold will permit holding castings to closer dimensions and insures greater uniformity. Shrinkage allowance is the same as usual; but about 2 deg. more draft is required.

The surface coating is little affected by alternate heating and cooling. Moisture in the mold or careless operation may injure the coating, but repairs are inexpensive and easily made by the operator who applies some of the wash from which the "stone facing" is built up. The wash, consisting of water, powdered fire clay and water glass, is applied cold to the heated mold. The time required for molding a casting such as a piston is 47 sec. The mold temperature runs from 940 to 1000 deg. fahr. and a constant temperature is reached after the first 8 or 10 castings are poured. The castings are at about 1625 deg. fahr. when dumped. The cores used are made of sand that is blown into the core box. They are dipped in clay and graphite on account of the pressure put upon them in the mold. Metal cores were tried but were not found satisfactory.

P. M. Heldt contributed some interesting remarks on current automotive engineering developments.

TRAFFIC CONGESTION AND RELIEF

New State Highway to Connect Vehicular Tunnel and Delaware River Bridge

Trunk Highway Motor Traffic was the topic of an instructive paper by Major William G. Sloan, State highway engineer of New Jersey, presented to the Metropolitan Section at its monthly meeting on March 13, at the Automobile Club of America, New York City. Among those whose comments added interest to the meeting were Walter Kidde, commissioner of State highways of New Jersey; Col. F. S. Greene, superintendent of public works of the State of New York; Major W. A. Welsh, a member of the Interstate Park Commission; M. W. Weir, A. J. Scaife, President H. M. Crane, C. O. Bech and F. C. Horner. Dr. W. K. Hatt, of Purdue University, and S. P. Thacher, of the United States Rubber Co., who were unable to be present, sent written discussions, which were read.

Major W. G. Sloan

Major Sloan said, in part, that, as a result of the amazing progress being made in all lines, the social and industrial life of the Country had been revolutionized and transportation mediums had been taxed beyond their capacity. To meet the increasing demands placed upon them, the railroads have constructed new lines, reconstructed other milage and made various improvements to effect economy of operation. The motor-truck problem is similar to that of the railroads. The railroads concede that short-haul business can be handled more economically by motor trucks; but adequate facilities must be provided for operating them or the development that has been produced and the accompanying increase of property values will be lost. This is illustrated by the arrested development of the coast of New Jersey, the location of many summer resorts. When highways become so congested that they cannot take care of the traffic they are of no more benefit to a district than are unimproved highways.

In certain Middle Western States there is one automotile to every five persons; the flattening out of the curve indicates that during the next 10 or 15 years the ratio will probably be about 1 to 4. The traffic in any locality varies somewhere between the one-half power and the first power of the number of vehicles licensed. On this basis, the traffic in 14 years will be approximately 2.7 times its present volume, but the ratio of trucks to passenger cars will increase.

New Highway Across New Jersey

Traffic congestion at both ends of the highway between Jersey City and Camden will be greatly increased by the opening of the Hudson River vehicular tunnel and the completion of the Philadelphia-Camden bridge. On the northern end, the proposed improvement will extend for 13 miles from the tunnel to a point beyond the city of Elizabeth, where it will connect with the State highway route. The minimum hourly count over this route is expected to be about 5500 vehicles, or about twice the number passing 42nd Street on Fifth Avenue. The gradients and curves have been designed so that trucks can be operated without changing gears. In Jersey City the highway will go through an open cut below the level of the streets, which will be carried over the cut on bridges; it will pass around Newark and Elizabeth to avoid local traffic.

Besides eliminating grade crossings, not only of railroads but of other roads, the highway will reduce the rise and fall by 20 ft., which will produce a saving of fuel sufficient to pay for the cost of constructing the highway and will aid in speeding up the traffic. The surface of the highway, which will have a minimum width of 50 ft., will be of granite blocks laid on a heavy concrete base. At Camden at the south end the traffic will be heavier than at Jersey City, owing to the fact that the main highway will carry the traffic of three converging State highways; here the roadway will be widened to 80 ft. If the railroads should decide to construct special yards near the largest centers for handling and distributing short-haul freight by motor trucks, this additional traffic must be provided for.

Lack of money alone has so far prevented the proper extension of highways; although the sums available seem large, the total mileage over which they must be distributed makes them inadequate. The total amount available for New Jersey per year from bond issues, licenses and Federal aid is about $19,000,000. Compared with this the people of the State spend yearly $78,000,000 for gasoline and tires and have spent not less than $440,000,000 for the vehicles themselves.

Use of Concrete in Highway Construction

Because of the variable conditions encountered in the building of roads experience must be the controlling factor. Soils when dry furnish a satisfactory base but when moist become plastic and unsuitable; they become much more stable when mixed with portland cement or lime. Then the change of volume between the dry and the wet states is less. Inter-

posing a layer of pervious material, such as sand or cinders, between the sub-base and the bottom of the pavement spreads the lead over a greater area and correspondingly reduces the pressure per unit area.

Roads made in the past that are not sufficiently rigid to carry the heavier loads of today will probably continue to be used where the loads are light. The only material that will withstand the heaviest traffic is concrete, but concrete possesses elasticity and undergoes stresses due to moving loads and to changes of temperature and moisture, so that expansion joints are necessary at intervals of 60 ft. Heat causes the edges to curl up during the daytime and to curl down at night. Although the consequent expansion and contraction is only about 0.01 in., a heavy truck passing over the road would be likely to break off a piece of the pavement, and from that time on the destruction of the road would be rapid.

In modern construction the sides of the road are made somewhat thicker than the center. When concrete is laid for the full width, the road usually cracks in the center, so modern roads have a longitudinal joint along the center line that increases the strength four times; but it also increases the number of corners. In general, concrete roads are designed for a maximum fiber-stress not to exceed 50 per cent of the ultimate tensile-strength of the concrete, as tests have shown that, although subject to fatigue, concrete may be stressed indefinitely if the stress does not exceed this amount.

Three types of wearing surface are in use at the present time: (*a*) bituminous mixtures, (*b*) concrete and (*c*) granite block. Bitumin is sufficiently strong for light loads, but is slippery in wet weather; concrete must be laid monolithic with the base and is not renewable, but will last for 15 to 20 years; for the heaviest traffic granite blocks are the best.

Reduction in Operating Costs

The annual cost of gasoline and tires in this Country has been estimated to be approximately $2,500,000,000. As a saving of about 25 per cent in these items is effected by good roads, their value is apparent. Descending traffic requires lower gradients than ascending traffic. When based on an operating cost of 10 cents per car-mile, the capitalized value of saving 1 ft. of the rise and fall of a road without increasing the distance is shown to vary from $2.40 to $19.00 per 100 vehicles per day, for grades varying from 2 to 5 per cent. This saving capitalized at 5 per cent would range from $47.50 to $380 per year. Figured in the same way, the saving of 20 ft. in the rise and fall of the highway through Jersey City would amount to $79,930 which, capitalized at 5 per cent, would amount to $1,500,000.

The conclusion reached is that shortening the distance to be traveled, especially where the traffic is heavy, reducing grade crossings and applying other principles of economics to highway construction and design, will reduce the cost of operation probably 50 per cent.

Points Raised in the Discussion

In opening the discussion Dr. Hatt, in his written comment, raised the question of the use of granite-block construction as reflected in the operating expense and the depreciation of vehicles and said that these items might entirely overbalance the extra wearing quality of the granite surface.

The streets along the New Jersey coast, according to Mr. Thacher's written discussion, were laid out years ago and contain a right-angle turn and several jogs. He said that much congestion of traffic could be avoided by simply straightening the highway.

Mr. Weir said that no machine is efficient unless operated continuously without slowing up; that the importance of eliminating grade crossings in accomplishing this result could not be overestimated. The expense of transportation is proportional to the loss of earning power due to operating in an inefficient manner. The price placed on short haulage by motor truck through congested districts is calculated on the basis of the time consumed and not on mileage. Statements of the number of vehicles per capita, he said, do not convey a full idea of the congestion in sections where automobiles from miles around concentrate on special occasions. Many drivers do not take their cars out on Saturdays, Sundays or holidays because of the danger and the inability to move with expedition. Present conditions with regard to the streets may be likened to a two-story building upon which it has been decided to add more stories. Broadening the streets is like underpinning a crumbling foundation. It is suggested that one cause of congestion might be removed by stopping excessive centralization and excessively high superstructure. Another method would be the establishment of yards by the railroads at convenient points that are free from congestion, where they could break bulk and from which the goods could be distributed to their destinations by motor trucks. New centers would be set up from which new roads could be laid out.

Major Welsh congratulated the State of New Jersey on having a body of men on the Highway Commission who have the courage, foresight and vision to lay out a system of real highways in the State and to disregard all local and political influences that might prevent their going where they wanted to go. They had built the best concrete road that he knew of in the United States with prison labor. They have made a close study of traffic conditions and have worked out some very difficult problems. The days of the railroads for anything but long hauls are numbered; the motor vehicle must be depended on for the short haul. But progress is slow because of the lawmakers. A bridge more than 5 ft. long cannot be built without a special act of the Legislature. New York State cannot buy right of way; the county and town must do that. Highways run around corners because the authorities will not condemn a piece of property worth possibly $500, but make the people burn $5,000 worth of tires going around those corners. Laws governing transportation have not been brought up to date. The law says that the highway belongs to the people, that all have a right to use it, but it does not give to anyone the right to use the highway to make money. Railroads and trolleys buy their right of way. What will be done with persons who operate bus lines and freight lines over the highways?

Major Welsh said he could not see the necessity for a 50-ft. or for an 80-ft. highway. The railroads build four, six and eight-track roads. He does not believe in mixing traffic and in cars going in both directions at the same time on the same highway. Traffic must be separated, slow-moving traffic on one side of the road, fast-moving express traffic on the other; that from the opposite direction should be kept separate. He believed that a perfectly smooth highway was the most economical and did not think that granite could be made perfectly smooth or that it could outwear good concrete.

Mr. Scaife called attention to the facts that the Pennsylvania Railroad realized that it was expensive for a train to cross and recross the main tracks in distributing less-than-carload freight, and that the plan had been developed of loading freight at stations 60 to 65 or 70 to 100 miles distant, the trains going up one side and down the other. At the stations the train is met by several trucks that distribute the freight from these stations to other stations. In his opinion, it was only a question of time before the railroad would distribute freight directly to the doors of the consumers.

President Crane stated that the Board of Highway Research had had reports on all the details of highway engineering, except the question of a through highway route from one place to another. He had hoped that some day just such a report as Major Sloan had given would be made. He said that finding one's way from the Hudson County Boulevard to the various ferries reminded him of a nickel bounding from peg to peg in a nickel-in-the-slot machine. At several points near New York City the neck of the bottle is so small that traffic speed has to be reduced to 10 m.p.h. One of these is the bridge over the meadows at Bayside where two lines of cars going in opposite directions can barely pass.

Chairman Cornelius T. Myers explained his preference for

concrete roads as being based on the fact that they were pleasanter and safer to ride over at night because the surface reflects light better than does that of bituminous roads.

Trucks Not to Blame for Road Destruction

Having been called on by the chairman to sum up the various points made by other speakers and add a few of his own, Colonel Greene remarked that, in his opinion, the truck should not be condemned for breaking up roads but that short-sighted engineers and legislatures should be blamed for not building roads that would carry the trucks. To his mind, it was a question whether the Country was yet ripe for a road exclusively for trucking purposes; he believed that roads should be designed for both passenger cars and trucks. In his own designs he had allowed 9 ft. for each roadway. The Pipe Line Boulevard across Nassau County will be 36½ ft. wide, the two outside pavements being for trucks and the inside two for passenger cars. The outside lines will be separated from the inside lines by a 2-in. bituminous joint. The concrete at the outside will be 9 in. thick and the center portion 7 in. thick. As 9 ft., in his opinion, is ample allowance for a truck, 50 ft. seemed unnecessarily wide. In Westchester County, where the traffic is unusually heavy, an allowance of 10 ft. is made. The use of granite block, as described by Major Sloan, also seemed to be an unnecessary expense, for very few steel tires are used today. A concrete road built 10 years ago that had had considerable use, including that by many more steel tires than are in use now, had shown a wear of only ⅛ in., and the broom-marks on the concrete could still be seen. Pneumatic tires on trucks are constantly increasing in number and tend to make the wear less. If the wear on a road in 20 years were 1 in., at the end of that time a new 6-in. top could be put on. This would be much quicker and less expensive than using Belgian block.

Mr. Horner described the work of Committee IV of the Chamber of Commerce of the United States of America, which was particularly interested in the relation of motor vehicles to other transportation facilities with a view to coordinating them. He said that coordination was absolutely essential if ruinous competitive waste were to be stopped; that to make the truck fit into the scheme it would be necessary to have legislation that would give the major facilities authority to use the motor vehicle and that the adoption of the motor vehicle would be by a process of evolution.

Motor Trucks for Less-than-Carload Freight

In some cases the motor truck is endeavoring to handle traffic beyond its economic limitations and should be confined to collection and delivery at terminals as, other things being equal, it is cheaper to transport goods by rail than by highway. Each facility must fit into its proper place. In handling local less-than-carload freight by rail to such points as Paterson and Newark, not only the actual cost must be considered but the additional cost of handling other main-line traffic that is interfered with. Other questions such as the waste caused by letting freight lie for days at the station instead of delivering it immediately were outside the present discussion.

Walter Kidde added that no mention had been made of the advantage of distributing less-than-carload freight to New York City and adjacent points after it had been broken up at a distributing station located in the Hackensack meadows. In his opinion, it would be of great advantage to the State of New Jersey as a unit to have a complete tabulation made of its assets as a going proposition, including the cost of traffic and passenger operation, the investment in facilities, the relation they bear to the manufacturing industry and other functions of the State, and the relation of the building of roads to the expense account of all the other functions and to the great values in the State that lie undeveloped.

In closing the discussion, Major Sloan admitted that the use of granite sometimes was open to question, but said that under certain conditions it was the only thing to use, particularly on grades. Regarding the adoption of the 50-ft. width, he said they had planned for at least 25 years in the future, that to move 5500 vehicles per hour would require four lanes continuously, and that the additional lane had been provided for emergency use in case a truck should stop to deliver goods or should break down.

BRAKE TESTS MADE DESPITE BLIZZARD

Milwaukee-Mid-West Brake Meeting and Demonstration Arouse Considerable Interest

Close to 300 shivering spectators defied a typical Lake Michigan blizzard to witness the brake demonstration staged in Milwaukee by the Mid-West and Milwaukee Sections as a part of their joint meeting on March 14. Though somewhat discomforting to the onlookers, these weather conditions were suited ideally to the testing of brake equipment under the most adverse conditions. There was just sufficient slippery snow on the street to keep the interest of the crowd at high pitch hoping for the anticipated disastrous skid that never materialized. In a few cases skidding occurred but the cars maintained their forward direction without treating the spectators to any thrilling tail-spins. The comment must be made that the four-wheel-braked cars showed less tendency to swerve from their paths than did those having brakes on the rear wheels only.

The group of cars entered in the demonstrations was a most representative one, including Packard and Oakland cars equipped with two and with four-wheel brakes. Hydraulic brakes were demonstrated on a Chalmers sedan; a

Brake Demonstration in Connection with the Joint Meeting of the Mid-West and Milwaukee Sections
At the Left the Cars Are Shown Lined Up for Inspection before the Tests and at the Right Can Be Seen Some of Those in Attendance

W. S. James

A. Y. Dodge

Rickenbacker with mechanical brakes participated. One of the interesting demonstrations was given by a Marmon phaeton fitted with the Christensen type of airbrake that is being developed in Milwaukee. Balloon tires were shown in action on a Franklin phaeton in combination with a transmission brake.

While the demonstration was not intended to be a test or a contest, it enabled the members to visualize the greater stopping ability of the four-wheel brake as compared with the rear-wheel type. It served one other and probably more important purpose, the series of runs demonstrating clearly the inadequacy of the ordinary flag-stop-measuring-tape method of testing. W. S. James demonstrated two types of decelerometer as developed at the Bureau of Standards and it did not take long for the engineers present to see that this type of testing was the only one giving reliable, accurate and comparable results.

Council Makes Milwaukee a Section

After the completion of the brake demonstration, the program was continued with a dinner at the Milwaukee Athletic Club in cooperation with the members of the Milwaukee Engineering Society. L. C. Hill, assistant general manager of the Society, spoke briefly and announced that the Council had voted favorably on the petition of the Milwaukee members for a Section.

A. Y. Dodge, chief engineer of the Perrot Brake Corporation, read a paper setting forth the advantages of the mechanical type of four-wheel brake control. He reviewed the principal points made by Henri Perrot in his paper before the Annual Meeting.[1] These were: first, reduction of pedal pressure to a minimum; and, second, minimized brake-pedal travel. He then showed how these requirements were met with the Perrot type of servo-brake. Mr. Dodge said that recent tests have shown this form of internal brake to be 40 per cent as efficient in a reverse direction as when applied in the forward direction. This has led the Perrot engineers to consider the possibility of using this one standard form of internal servo-brake on all four wheels. Modifications made in Perrot brake controls by American engineers have reduced their cost 60 per cent from that of the European designs. A study of the pedal pressures that can be exerted by persons of different heights and weights in seats of varying proportions is now being made by Mr. Dodge and will be published shortly. He spoke at some length on the difficulties of securing complete equalization of braking effort at the four wheels and stated that he did feel that equalization beyond 85 per cent was of no consequence and even undesirable.

W. S. James repeated his extremely interesting and valuable talk on the Bureau of Standards brake investigations that he has given before the Annual Meeting and several Section meetings.

[1] See The Journal, February, 1924, p. 101.

Chairman G. W. Smith Secretary W. S. Nathan
Two of the Officers of the Recently Established Milwaukee Section

ENTRANCE TO A NEW SCIENTIFIC ERA

Optimism Expressed Forcefully Provided Fundamental Laws Are Comprehended

C. F. Kettering

"Things are labeled 'scientific' when a man desires to talk over the heads of his listeners, and he calls a project 'technical' when he doesn't understand it himself." This and other gems of philosophy were expressed by C. F. Kettering, president of the General Motors Research Corporation, Dayton, Ohio, during his address to an audience of some 400 members and guests of the Detroit Section on March 7.

His argument is for a concentrated study of the fundamental relationships of elementary science. The how and the why of fundamentals should be the basis of the approach to any problem because the fundamental laws of all sciences pertaining to matter are identical and capable of universal use. He said that engineering must partake as much of economic horse sense as it does of scientific principles and that all the abstruse calculations in the world mean nothing if the calculator has not a sound understanding of the relationships that enter the hypothesis. Without this understanding, a mathematical calculation is just like a trip through a railroad tunnel; you have gone in some place and come out some place but you do not know how you got there or where you have been.

Confusion and a lack of accomplishment in any given field result from the manner in which the truth regarding the fundamental laws is obscured by the complicated nomenclature of the various scientific bodies. Until all forms of

energy are utilized to the utmost, no branch of science is complete in itself or can be. This involves the knowledge of universal laws and requires a common understanding and a nomenclature of fundamental principles. The laws of all branches of science could be condensed into a 25-page handbook on elementary science that would deal only with fundamental mass and energy relationships.

When undertaking any new problem or development, science and economics should be combined. Engineering is merely the adaptation of fundamental materials to the utility of mankind. If the cost of this transfer is more than the public will pay, the proposition is doomed to failure and all the scientific theories in existence will not save it. The terms "research," "scientific" and "technical" too often constrict new ventures and do not connotate the necessity for making something useful at a price that prevents failure of the organization. "Research" is sometimes a convenient label for obtaining an appropriation about which some doubt exists.

Instead of adapting our mode of thought to its solution, too often we attempt to change the problem itself; we think in ruts and continue to approach new problems from the standpoint of past knowledge only. Fundamental knowledge, economic judgment and pioneering thought are bringing engineers to the threshold of scientific development and, as this progress continues, new applications of energy will be utilized to relieve the present demands. The limit of development is scarcely conceivable; only the surface has been scratched thus far. A tremendous influence toward hastening achievement lies in the increasing knowledge of fundamental relationships.

DROP-CENTER RIM SUITS BALLOON TIRES

Tire Changing Easier and Rim Is Lighter, Less Expensive and Reduces Side-Roll

Drop-center rims of the Dunlop type seem to be particularly suited for use with balloon tires. At least that is the conclusion one drew from the interesting meeting of the Buffalo Section on March 24 when the merits of the drop-center rim were set forth in a paper by H. Wilshaw, chief engineer of the Dunlop Tire & Rubber Corporation. The ease with which balloon tires can be mounted and dismounted on the drop-center rim is alone sufficient reason to warrant its receiving the careful study of every progressive engineer. Disadvantages may be cited against the rim by those who are wedded to conventional designs, but it is certain that motorists will lose sight of these once they have had the tire-changing advantage demonstrated to them. After having experienced the struggle with broken spring-leaf, screw-driver and hammer to remove a high-pressure casing from one of the conventional demountable rims it is a revelation to see how handily a 7.75-in. section balloon tire can be slipped on and off the drop-center rim with no tools other than the hands. It has been said with some truth that the motorist forced the use of the balloon tire; it is not unlikely that they may force the use of drop-center rims when they are acquainted with their tire-changing advantages. Mr. Wilshaw's paper contains many interesting statements and these are abstracted in the following paragraph for the benefit of our readers.

H. WILLSHAW

The balloon tire is generally made up of coarse fabric plies varying from three to four in number and in some cases the ply material is also of lesser weight per yard than that used in high-pressure tires. This means that together with the greater cross-section of the balloon tires, the tire has the degree of flexibility required in a tire that takes full advantage of the drop-center rim feature. Since the side-walls of the balloon tire are thin and flexible, it can be easily placed on or removed from the drop-center rim. To remove the tire the air is released from the tube, then the tire side-beads are pressed inward from the bottom or base of the rim and downward into the well of the rim. When the beads have been pressed into the rim well, as shown at the upper right of Fig. 1, it will be observed that sufficient clearance is available diametrically opposite the place where the tire sides were first pressed inward, to enable the bottom portion of the tire to be pulled off the rim by inserting the fingers between the rim and the tire beading.

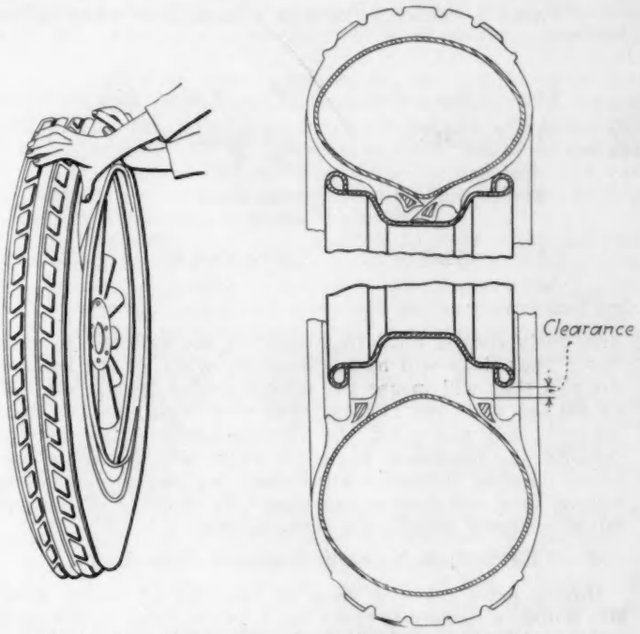


FIG. 1—HOW DROP-CENTER RIMS FACILITATE TIRE CHANGING
Illustration at Left Shows Beads of Deflated Casing Being Pressed Inward and Down into Channel in the Center of the Rim. When Beads Are in Position Shown at Top of Section at Right, the Casing Drops Down so That Sufficient Clearance Is Provided at the Bottom to Allow the Tire to Be Pulled Sideways Off the Rim.

WIDE-BASE RIMS RECOMMENDED FOR BALLOON TIRES

In studying balloon tires several years ago the Dunlop Corporation endeavored to proportion the rim correctly to the particular size of the balloon tire called for. It was known from practice that if the tire section increased out of proportion to the rim width the low-pressure tire would have a tendency to roll sideways and under some conditions the wheel would fail to track correctly, thus rendering steering difficult. The proportions of the high-air-pressure tire and rim were consequently set down and an angle of stability found. This is represented by the angle Θ shown in Fig. 2 between the lines connecting the tread center on the ground and the points where the casing is tangent to the rim flange when the tire is inflated with normal air-pressure but not under load. Having drawn this angle of stability for high-pressure tires, it seems sound to build up an enlarged casing for the balloon tire by projecting the sides of the triangle

TABLE 1—ANGLE OF STABILITY FOR VARIOUS TIRES

Size and Kind of Tire	Angle of Stability, deg.
32 x 4-In. High Pressure	38
5.25-In. Balloon Tire on a 4-In. Standard Rim	31½
Balloon Tire on a Drop-Center Rim	42

TABLE 2—RELATION OF THE SIDE-ROLL OF TIRES TO THE ANGLE OF STABILITY FOR VARIOUS TIRE AND RIM COMBINATIONS

Test	Tires Fitted	Type of Rim	Rim Width, In.	Angle of Stability, Deg.	Air Pressure, Lb.	Pull, Lb.	Roll Measured at Rear Hub Cap, In.
1	33x5	Goodyear Wood	3.12	32½	60	500	1/4
						1,000	1/2
						1,500	1–3/8
2	7.30/20	Goodyear Wire	3.75	31	25	500	1/4
						1,000	5/8
						1,500	1–1/16
3	36x8	Drop-Center	5.25	40	25	500	1/4
						1,000	1/2
						1,500	13/16

previously formed until they intersect the balloon-tire base-line. Thus there will be indicated the width of the balloon-tire rim that will insure the same stability against side-roll as did the narrower rim equipped with high-pressure tires. As previously mentioned, the high-air-pressure tire angle of stability was considered as the minimum, and this angle was, where possible, increased when designing and proportioning balloon tires and drop-center rims. An example of the different angles of stability is given in Table 1.

Effect of Narrow Rims on Side-Roll

Having noted peculiar wear on the sides of certain tires, Mr. Willshaw decided to carry out a test on a car with a view to determining the amount of side-roll of the tires in relation to the angle of stability with various tire and rim combinations. A rope was passed around the hub of one wheel and the other end of this rope was attached to a block and tackle anchored to a steel column. A spring scale was placed in the rope circuit so that the load or pull on the rope could be measured. As a load was placed on this rope, the side movement of the hub cap with relation to the ground was carefully measured. The results of this test are given in Table 2. It will be observed from this table that the amount of roll was nearly proportional to the rim width and also to the angle of stability; also that the tire with the widest rim and the greatest angle of stability gave the least side-roll.

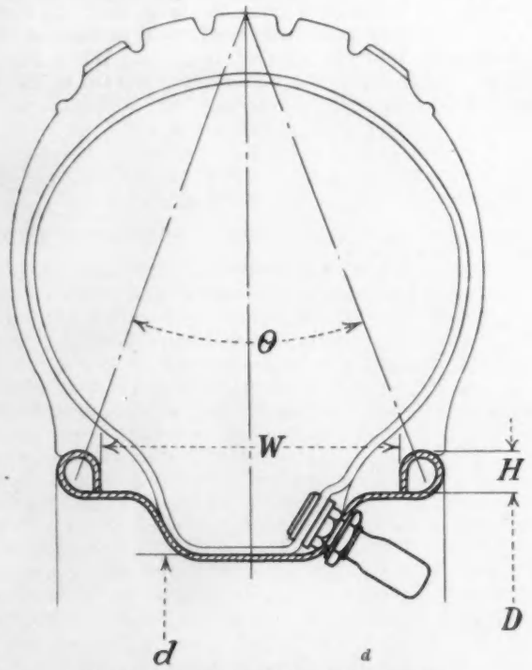


Fig. 2—Drop-Center Rim Proportions

Tire Section	D	d	H	W
4.75	21	19.374	0.59	3.25
5.25	21	19.374	0.59	3.25
6.00	21	19.000	0.70	4.00
6.75	20	18.000	0.70	4.25
	21	19.000	0.70	4.25
7.75	20	18.000	0.70	4.75
	21	19.000	0.70	4.75

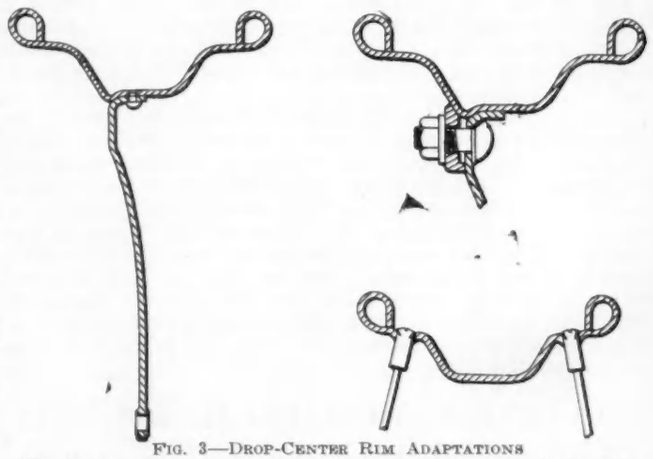


Fig. 3—Drop-Center Rim Adaptations

The Section at the Left Shows the Drop-Center Rim Riveted to a Disc-Wheel That Is Demountable at the Hub. The Rim in the Upper Right Section Is Demountable at the Rim. Drop-Center Rim Construction for Wire Wheels Is Shown at the Lower Right.

Although a wide-rim base is advocated and can be used advantageously with the balloon tire, it does not mean that the drop-center rim has to be made heavier than rims of present-day standard practice. Owing to the fact that the drop-center rim is a much better structure than the conventional rim, the actual weight of the rim can be reduced by about 7 lb. Because of its peculiar section, the drop-center rim is actually stiffer against a side strain than the conventional type of rim. It also provides from 6 to 8 per cent additional air space for the tube as compared with the standard type of rim. It should also be noted that a troublesome loose flap to protect the inner tube is not needed when the drop-center type is used. Note from the section shown in Fig. 2 that the valve-stem projects from the rim in a most accessible position.

Unsprung Weight Reduced by Drop-Center Rim

To the rim manufacturer, the drop-center rim means reduced cost, simplification of manufacture, easier rolling of the sections and better balance of shop conditions since the rim is completed after leaving the final flanging roll. An extremely interesting point to the automobile engineer is the fact that the drop-center rim effects a considerable reduction in unsprung weight. This saving may amount to from 8 to 16 lb. per wheel by the adoption of drop-center rims. Fig. 3 shows how the drop-center type of rim is adapted to steel disc-wheels detachable at the hub, steel disc-wheels detachable at the rim and to wire wheels.

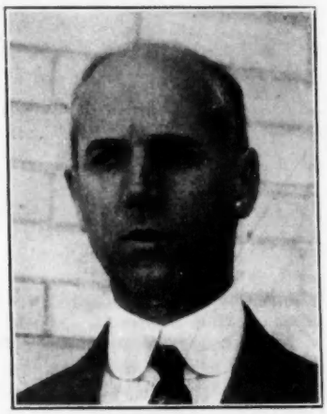
Questions raised in the discussion of Mr. Willshaw's paper indicated that the engineers present were skeptical of a deflated tire being able to stay on the drop-center rim in case of a blow-out. Mr. Willshaw answered this criticism by saying that he had driven cars as far as 5 miles with one tire deflated and the casing showed no tendency to leave the wheel. F. H. Meyer, of the American Welding & Mfg. Co., said that from the rim manufacturer's standpoint a one-piece rim is desirable. He believes the Dunlop type of rim entirely practical. Its cost would be less because of a saving in material and the absence of the retaining ring.

L. H. Pomeroy commented at some length on Mr. Willshaw's paper. He cited hard steering as the worst disadvantage of the balloon tire and believed that it might be necessary to rearrange the steering linkage entirely on the new models to solve this problem. He criticized the present lack of standard balloon-tire sizes and hoped that the Society would be successful in its efforts to bring about an agreement between the tire makers and the car builders on a suitable standard. J. W. White, chief engineer of the Buffalo Wheel Corporation, said that he had noticed excessive sidesway or swerving when balloon tires were mounted on narrow-width rims. He had found this unpleasant driving sensation much relieved when driving with balloon tires mounted on wide-base drop-center rims of the Dunlop type.

REVIVAL OF PENNSYLVANIA SECTION

Balloon Tires and Riding Quality Discussed by J. E. Hale

On March 11 the Pennsylvania Section held its first meeting of the season, with John Younger, chairman of the Cleveland Section, as the presiding officer. One hundred and twenty-five members and guests were present.



J. E. Hale

Henry M. Crane, president of the Society, extended to the Section felicitations on the resumption of its activities. He emphasized the point that the real spirit of the Society is brought home to the members in meetings of the Sections and observed that the main consideration is not how many meetings a year a Section holds, but what it does well.

In referring appreciatively to the work on Sections problems of the Special Committee on Society and Sections Organization, of which Past-President Bachman was chairman, Mr. Crane said that difficulties in general encountered in the conduct of Sections cannot be obviated hurriedly, and that no substitute for somebody doing hard work in a Section has been found; real work determines whether or not a Section is successful.

In addressing the meeting on the subject of balloon tires, J. E. Hale, manager of the development department of the Firestone Tire & Rubber Co., supplemented the papers he had presented on the same general subject at the 1923 Semi-Annual Meeting of the Society[1], and at a meeting of the Indiana Section[2] held several months ago.

Characteristics of Balloon Tires

Mr. Hale said that the cord tire had increased three-fold the service that had been rendered by the fabric tire, and the balloon tire is another improvement, this type being defined as incorporating a thin flexible structure of larger cross-sectional area than ever before for passenger-car equipment, a four-ply carcass and a light tread that flexes about as easily as the side-wall. The method of fitting this tire to its rim is substantially the same as in the case of the other type of cord tire recently and currently used.

Mr. Hale expressed the belief that the final rim-diameters for balloon tires will be 20 or 21 in. Special equipment for repairing balloon tires has been developed.

The balloon tire is based on the idea of using lower air-pressure and yet securing satisfactory service. Mr. Hale said that from 25 to 30 lb. is the proper air-pressure, this giving much easier riding and protecting the car against the effects of vibration. He stated that the traction and braking effects are better with balloon tires, particularly on wet pavements.

Mr. Hale gave some figures to substantiate the claim that the gasoline economy is somewhat better with the balloon than with the high-pressure tire; a taxicab averaging 12.6 miles per gal. with the latter as against 13.5 miles per gal. with the former. The stiffness of the high-pressure tire balances the greater rolling resistance of balloon tires; balloon tires do not bounce as much in running.

At low speeds it is more difficult to steer a car equipped with balloon tires. Mr. Hale said, however, that very little difference in steering is noticed in ordinary driving.

Among the statements made and the expressions of opinion advanced by the speaker were those that pavement irregularities result in sharp vibratory reaction with high-pressure tires, whereas with balloon tires the effect of such irregularities is largely obliterated; the balloon tires must be of deep section, as well as be inflated at low pressure; the installation of shock-absorbers is necessary with balloon tires; and covered lubricated springs are an element in securing the best all-round riding effect.

Mr. Hale advocated 25 to 30 lb. inflation-pressure for the type of tire he was discussing, for all sizes of car, stating that this would not result in premature tire failure but in normal tread wear and not collapse of the carcass. The limiting factor is vertical deflection. The cotton cords deteriorate in tensile-strength gradually in service.

The speaker added that whereas in former practice it was customary to have the width of rims amount to 60 per cent of the cross-sectional diameter of tires, recent developments have resulted in the reduction of trouble with the beads of tires and rim width is now determined only by the amount of room necessary for the valve between the beads. Mr. Hale is of the opinion that, in addition to being lighter and lower in cost, a relatively narrow rim provides better conditions for the flexing of the tire.

Size and Standardization

Heretofore the nominal dimensions of tires have varied greatly from their actual dimensions. The dimensions 4.40, 5.25, 6.20 and 7.30 in. are supposed to indicate the actual cross-sectional diameters of the respective balloon tires in their inflated condition. With respect to the standardizing of a list of balloon-tire sizes, Mr. Hale said that he considered ridiculous the list of 23 sizes that has been published recently. He stated that the five sizes for 20 and 21-in. wheel diameter that had been approved recently for inclusion as general information in the S.A.E. Handbook are the sizes of the balloon tires that are used most widely at present.

With regard to the durability of balloon tires, Mr. Hale asserted that when properly installed the tires will give mileage in excess of that securable from the high-pressure tires; that, owing to the softness of the tire and the low pressure to which it is inflated, no difficulty is experienced with tread separation in the case of the balloon tire; and that the treads wear very smoothly, with a marked absence of cutting or chipping, for the reason that the tires do not "fight" the road. But he warned against under-inflation, on the basis that the vertical-deflection limitation must be allowed for. However, in the case of the balloon tire the inflation-pressure recommended will permit the riding comfort desired.

After pointing out that no tube or valve will hold air indefinitely, the speaker told the members that the puncture hazard is not much if any greater with the low-pressure than with the high-pressure tire. He disavowed optimism as to the success of semi-balloon or balloon-type tires, apparently feeling that the inflation-pressures upon which owners will insist in the actual use of their cars will cause premature failure of these types of tire; disastrous bruises and also bead trouble resulting under such condition, owing to the bottoming of the tire on the rim when the tire cross-sectional diameter is not great enough.

In answer to a question, Mr. Hale said that on cars equipped with balloon tires wheel-wabble had been encountered which had not developed when high-pressure tires were

[1] See The Journal, July, 1923, p. 41.
[2] See The Journal, December, 1923, p. 461.

used, the difference existing mostly at speeds above 60 m.p.h. He expressed the belief that at speeds of 30 m.p.h. wheel-wabble with balloon tires is ascribable to loose connections in car parts. However, the wheel-wabble under high-speed conditions is, in Mr. Hale's opinion, not well understood.

With regard to vertical drop of high and low-pressure tires after sudden deflation, he gave the following figures:

5.00-in. high-pressure tire	3.70-in. drop
7.30-in. low-pressure tire	4.75-in. drop

He said that he was satisfied that there is no danger from blowouts with low-pressure tires. The tubes for balloon tires when inflated are of substantially the same thickness as tubes for high-pressure tires. In discussing general points, Mr. Hale stated that the superior service the balloon type of tire gives is attributable to the fact that it does not slip on the road and that its performance during coasting and acceleration is practically the same as that of the high-pressure tire.

Applicability in Motor Truck and Bus Fields

No special type of balloon tire has been developed for use with motor trucks, although the 7.30-in. regular balloon tire may be installed on "speed-wagons." Mr. Hale predicted that, although considerable development work remains to be done, the balloon tire will have many advantages in bus service; in fact, the 7.30 tire now developed will, he believes, probably be satisfactory for 15-passenger buses equipped with one tire per wheel. He had not heard of dual balloon-tire equipment being considered but did not see why that would not be feasible.

A. K. Brumbaugh said that in the use of heavy-duty pneumatic tires for motor trucks, it had been found repeatedly that making a sharp turn at moderate speed was followed by a tire going flat. A diagonal rip was found in the side-wall, this being due to the effect of side-sway or of engine torque-reaction on the tire side-wall. He raised the question whether such strains would not result in the ripping of the side-walls of balloon tires, particularly in use on trucks for industrial or military service in which, due to large gear-reductions for heavy pulling, the tires would be subjected to great stresses.

C. H. Dengler stated that it had been calculated that a motor vehicle with 10-in. balloon tires could carry a load of 3½ tons across the Sahara Desert.

Car-Mile Cost

With regard to mileage secured with balloon tires, Mr. Hale mentioned the following results in taxicab service, with tires that are still running: 1 tire ran over 20,000 miles, 2 tires 15,000 to 20,000 miles, 12 tires 12,000 to 15,000 miles and 11 tires 10,000 to 11,000 miles. He spoke of one set of 7.30-in. tires that had run over 23,000 miles on a passenger car.

In reply to a question, Mr. Hale said that speaking generally he believed that balloon tires will cost very little more than the high-pressure tires, but that he felt sure that the cost per car-mile with the former would be less; moreover, that, taking into consideration the reduction in car maintenance expense that the balloon tire will effect, the resultant saving from use of the balloon tire will be considerable.

W. M. Newkirk related some personal experience with balloon tires. He was of the opinion that somewhat shorter and stiffer springs can be used with low-pressure than with high-pressure tires if it is not desired to improve materially the conventional riding quality with tires of the latter type. However, to get the best result spring design must be considered in the same general way in connection with both types of tire. Mr. Newkirk said that under some conditions, such as a lawn that has been softened by frost coming out of the ground, 6.20 tires will sink and dig in to such an extent that the car cannot be driven on them, because the ground is just soft enough and the grass slippery enough to prevent this being done. The balloon tire will negotiate ordinary soft mud or sand. Mr. Newkirk said that in his own driving the gasoline economy had not been so good with balloon tires as with ordinary cord tires.

B. B. Bachman brought up various points relating to the maintenance of the proper inflation-pressure for balloon tires. In reply Mr. Hale said that four-ply large-section balloon tires should not under any circumstances be inflated to a greater pressure than 35 lb. A pressure of 40 lb. causes such a tire to puncture relatively easily.

PAINT DURABILITY BEING INCREASED

Introduction of Pyroxylin Materials Has Stimulated Research in Body Finishes

H. C. Mougey

Methods of finishing automobile bodies and metalwork were reviewed fully in a paper by H. C. Mougey, control chemist of the General Motors Research Corporation, before the Dayton Section on March 21. Mr. Mougey described the various materials used for painting and enameling, stating the advantages and disadvantages of each. He expressed the belief that the length of life of automobile finishes will be materially lengthened in the near future by reason of chemical research being conducted by the paint companies and the attention the subject is receiving on the part of body builders.

Mr. Mougey said that in the case of bodies containing wood and glue in their construction the effect of high drying temperatures presented a problem. The wood will stand very high temperatures without injury, but it dries out rapidly and warps, thus subjecting the glued joints to mechanical strains. Owing to the effect of these strains on the glued joints, little dependence should be placed on the glue and all important joints should, therefore, be reinforced with mechanical fittings, bolts or screws.

It is believed by the General Motors Research Corporation engineers that in most cases higher drying temperatures than those used will be an advantage. However, it is almost always necessary to dry the finishing varnish at a low temperature to prevent softening of the undercoats and thus injuring the luster of the finishing varnish.

Failure of Undercoats a Source of Paint Trouble

The real cause of the short life of the ordinary automobile finish is the failure of the color and rubbing varnishes which, as they crack, break down the finishing varnish along with them. More durable color and rubbing varnishes help this condition, since the life of the finish will then depend on the durability of the finishing varnish rather than that of the undercoats. Finishing varnishes ordinarily used in production fail when given 3 months' summer exposure on test racks at an angle of 45 deg., facing south.

The adoption of cellulose nitrate finishes has had a very stimulating effect upon the paint and varnish industry. New finishes are being developed which will introduce new materials or new methods or both.

Dayton Section Founds Wright Medal

An important step was taken by the Dayton Section at this March meeting. It was voted to set aside $1,000 of the Section's funds for the purpose of creating what will be known as the Wright Medal Fund. While the plans are yet tentative, it is proposed to present a medal each year for the best paper prepared by a member of the Society on any aeronautic subject, this paper to be selected by a committee of the Dayton Section and presented before one of its meetings.

AUTOMOTIVE RESEARCH

The Society's activities as well as research matters of general interest are presented in this section

RESEARCH COMMITTEE MEETS

Five Major Projects Included in 1924 Program of Important Work

Automotive fuels, truck transportation costs, riding qualities and gears are among the major projects now before the Society's Research Committee. Highway investigation, an important project of the Highways Committee, is also one of the subjects under consideration by the research body. Several of the above items will be recognized as continuing projects that were initiated some time ago, while others are of more recent origin.

Automotive Fuels

Progress in the automotive fuels investigation undertaken jointly by the Society, the American Petroleum Institute, the Bureau of Standards and the National Automobile Chamber of Commerce has been reported from time to time before the Society and in The Journal, notably in the January, February and July, 1923, and February, 1924, issues.

The major portion of the general investigation has been carried on in the automotive powerplants section of the Bureau of Standards, the object of the work being to determine the effect of fuel-volatility upon the performance of automotive engines. In addition to this investigation at the Bureau, extensive road-tests have been conducted in cooperation with 10 of the larger automobile-building companies. The various tests have been run under both summer and winter conditions and have included the study of crankcase-oil dilution as well as fuel consumption and other important features of engine performance.

The cooperative work with the automobile companies has been concluded for the present, but the Bureau of Standards tests are being continued in order that the subjects of dilution and starting may be investigated further.

The dilution work now in progress includes a study of the effect of jacket-water and air temperatures and a determination of the rate of increase of dilution with continued operation. It is hoped that additional information concerning the effects of dilution and dirt may also be obtained. In connection with starting, the tests will determine the lift and the gas velocities required for starting; the question of piston-leak and the effect of spark characteristics upon starting will also be investigated.

Truck Transportation Costs

Fuels, tires, upkeep, depreciation and time are among the most important cost-factors involved in truck transportation. An investigation of the variation of these factors with different types and conditions of highway has been undertaken by the Society in connection with the highway research program of the National Research Council.

To date a certain amount of reliable information on the subject has been placed at the disposal of the Society by truck operators, and efforts are being made to obtain as many more useful figures as may be available. Fleet operators have willingly cooperated in the work and, in spite of the apparent scarcity of dependable data, it is hoped that the investigation may soon reach the point where important conclusions can be presented.

Riding Qualities

What are the basic factors that determine the riding qualities of automobiles? Comparatively little information of value in answering this question is available. Most of the research touching upon the problem has dealt with comparatively restricted phases of the broader question. A careful and systematic study of the subject should determine the controlling factors and thus assist in establishing a rational basis for the design of vehicles.

The Research Committee hopes by cooperating with others to advance the solution of this problem. It is expected that a workable program of research will develop in due time. A comprehensive study of the literature is already in progress, and consultations are being held with engineers whose interests and activities lie in this and in associated fields. Contact is being established with medical and psychological agencies which will undoubtedly play an important part in the consideration of the problem. A round-table conference arranged by the Society at the time of the Annual Meeting in Detroit served to bring out many interesting facts and to reveal the importance that the subject assumes in the minds of our leading engineers. Reports of this gathering were printed in the February and March, 1924, issues of The Journal.

Gears

An ever-present conundrum is the gear problem. Smoothness of operation, freedom from noise and vibration and many other factors involved in design are as yet far from being satisfactorily solved.

Manufacturers and designers have presented their views to the Society through correspondence with the Standards Department. That many of the obstacles which lie in the way of satisfactory gear standardization can best be solved by research seems to be generally admitted.

For this reason the Research Committee is undertaking to investigate the problem. In this connection it is planned to hold a meeting, perhaps during a general session of the Society, at which gear matters can be discussed and definite plans for active research made.

Highways

Cooperating with the Bureau of Public Roads and the Rubber Association of America, the Highways Committee, B. B. Bachman, chairman, is participating actively in a series of impact tests with trucks on highways. The Research Committee is also interested in many phases of this research which it is hoped will bring out a mass of important data relating to the durability of highways with the types of truck that use them. Certain of the forces to which trucks are subjected in service will in turn be determined. The question of tire equipment enters as a most important feature of all the tests.

To date the research has been confined largely to matters of instrumentation that must be properly settled to make the test-results dependable and of the greatest value. It is expected that the impact tests will be in progress in the near future.

Certain features of the program were discussed in the July, September and December, 1923, issues of The Journal.

HORNING HEADS RESEARCH COMMITTEE

Specific Projects Are Assigned to Subcommittees or Groups

The importance of research to the Society and to the industry is emphasized by the willingness of many leading engineers to participate in our activities in this field. During the year 1924 the work will be directed by the following committee:

H. L. Horning, *Chairman*

H. W. Alden	T. J. Litle, Jr.
B. B. Bachman	T. Midgley, Jr.
O. C. Berry	F. C. Mock
H. M. Crane	A. L. Nelson
H. C. Dickinson	S. W. Sparrow
W. S. James	P. S. Tice
E. A. Johnston	J. G. Vincent
C. F. Kettering	E. P. Warner

R. E. Wilson

Group Organization

In order that the work on certain of the major projects may be handled most effectively, the committee has adopted the plan of assigning these projects to the special attention of subcommittees or groups of members who specialize in the particular branches of research involved. The following personnel of the automotive fuels group has already been chosen.

O. C. Berry	F. W. Lane
H. M. Crane	T. Midgley, Jr.
H. C. Dickinson	F. C. Mock
H. L. Horning	S. W. Sparrow
W. S. James	P. S. Tice

R. E. Wilson

RESEARCH DEPARTMENT COOPERATES

Information Service and Journal Work Included in Routine Activities

It is the function of the Research Department, J. A. C. Warner, assistant manager, to assist in the administration and execution of the programs laid down by the committees as outlined above. The department activities include other important work.

Information Service

Through its information service the Department answers by correspondence and personal conference a great many technical questions from the members. In connection with this work, described in detail in the October, 1923, issue of The Journal, an extensive file of technical information is maintained. The Society's library of books and periodicals is also readily accessible.

The Research Department prepares for publication each month in the Notes and Reviews section of The Journal about 10 columns of abstracts of the most important current articles and books of interest to the members.

It is also responsible for the Automotive Research columns of The Journal where the Society's research activities and research matters of general interest are presented.

RICARDO'S LABORATORY REVISITED

Recent Activities of the Well-Known British Engineer Reported

One of the most interesting spots in England from the point of view of automotive research is Harry R. Ricardo's laboratory at Shoreham. This is not only a research laboratory in the usual sense, supplying its own special equipment, but it is a headquarters for special research equipment. One finds the products of the Ricardo shops here and there throughout England and elsewhere, in the shape of special machines designed for specific research problems. A considerable number of duplicates of the variable-compression engine that has been described in various publications have been built for other laboratories and more are now under construction.

Detonation

One of the variable-compression engines in Ricardo's laboratory is being used in an investigation of "pinking" with different fuels and fuel-dopes. Much of the resulting material has been published. The method of adjusting spark-timing for these observations is of interest. The criterion used is that maximum pressure should occur at 12 deg. past top dead-center. The position of maximum pressure is determined by a Royal Aircraft Establishment indicator[1] and the timing is set accordingly for each fuel, speed and compression-ratio. For all petroleum fuels, both with and without "dope," the timing is substantially constant for the same speed and compression-ratio. For benzol and alcohol blends a slightly greater advance is necessary than for petroleum fuels. It has been found that this setting gives both the maximum torque and the maximum tendency to detonate. Hence, for rough tests it suffices to set the timing for the maximum torque. Experiments with tetraethyl lead seem not to have shown any measurable difference between the rate of flame-spread in the fuel with and without dope up to the time of detonation. This conclusion is based not only on indicator-cards but on ignition by adiabatic compression. Both the time of pressure rise and the temperature of ignition are the same for the same fuel with and without dope.

[1] See The Journal, January, 1924, p. 68.

Crankshafts

A new experimental engine with a built-up crankshaft designed for durability in bus service has been built for the Tilling Stevens Co., the object of the design being to secure maximum hardness of the bearing surfaces. It is believed that in this way surfaces can be made harder than most of the abrasive material to be found in engine crankcases. If this is true, wear should be nearly eliminated. The engine referred to has roller bearings, though plain bearings are also used and preferred for some reasons. This engine had run over 100 hr. at full load with the cylinders removed, yet not the slightest evidence of wear could be noticed in the feel of the connecting-rods. Another engine of the same type was reported to show no more wear than this after 10 months in bus service.

Lubrication

The laboratory is regularly engaged in making service tests of lubricating oils, for which tests there are four special single-cylinder engines. These are being operated for comparison tests on different oils and on different amounts of oil supplied to the cylinder-walls to determine the effect of these variations on the engine and the oil. Tests are made of the carbon deposits, as to both the amount and the character. The deposits are analyzed for the metallic content as an index to the rate of wear of the engine parts. The oil samples after use are subjected to the usual laboratory tests to determine what has happened to them. An interesting feature of these tests is the measurement of engine friction. Once every ½ hr. each engine is allowed to stop from a fixed speed with the load removed and the intake-valve closed. A record is made of the time required for the engine to come to a stop. With reduced lubrication the differences between organic and mineral oils become evident. The tendency of an oil to form gum is detected readily; in fact, it is claimed that this stopping-test is the most sensitive one that has been found for detecting differences in the behavior of different oils.

A New Engine

An interesting new light-car engine of about 25 hp. is in the laboratory also. It has two cylinders side-by-side acting on a single-throw crank, with a harmonic balancer which is so effective that up to 2000 r.p.m. the engine is remarkably free from vibration. The cylinders, of overhead-valve design, have an ingenious valve-operating mechanism of push-rods operated from a cross-shaft. No immediate prospect of this engine going into production has been considered, but it looked much better and less expensive to build than many of the engines now on the road. Two-cylinder engines seem not to be in much favor, probably due to bad designs.

The attitude of the average Englishman toward his automobile is difficult to appreciate here. According to Mr. Ricardo, the automobile is not a necessity to the average Englishman, but is and is likely to remain a toy. The possessor of an automobile wants to have his individual ideas incorporated in it and does not wish to change every year. Style does not count for much. In short, the automobile in England is far from being the institution that it is here.

TENTATIVE STANDARDIZATION WORK

Criticism of all tentative reports should be sent to the Standards Committee in care of the Society

PRODUCTION DIVISION PROPOSED

Function of Division To Be Standardization of Production Methods and Tools

The organization of a Production Division or a Special Committee of the Standards Committee to prepare data sheets on standardized production methods and tools that would supplement the standards and recommend practices for parts and materials now published in the S.A.E. HANDBOOK, has been proposed and is under consideration by the Council.

Among the subjects suggested as coming within the scope of such a committee are dies, punches and jigs. It is thought by those interested in seeing this standardization undertaken that it would result in considerable savings to the industry, but it is appreciated that such an undertaking will involve careful organization and the active cooperation of the production departments of the car and the parts manufacturers.

To determine the consensus of opinion in reference to the desirability and feasibility of undertaking such a standardization program, the views of the Chairman and the Vice-Chairmen of the Standards Committee and of representative factory and production managers have been sought through a general letter sent out by the Standards Department. The Council will be guided largely by the comments received. Information in this connection was invited with particular reference to the following points:

Would standardization of production materials, equipment and methods be of economic benefit?

Should the work be undertaken by a Division of the Standards Committee or taken up jointly with other engineering organizations by sectional committees operating under the rules of the American Engineering Standards Committee?

Can it be expected that the individual companies will participate actively in such standardization if it is undertaken by the Society?

STANDARDS ACCEPTED BY THE SOCIETY

Letter-Ballot of Voting Members Confirms Action of Standards Committee

In accordance with the Standards Committee Regulations, the recommendations that were approved by the Standards Committee at the Annual Meeting in Detroit, and confirmed by the Council and Society action at the Annual Business Meeting were submitted by letter-ballot to the voting members of the Society. The results of the letter-ballot, returnable March 25, indicated that there was no large minority against the adoption of any of the recommendations. The comments submitted in support of the negative votes cast were of such a nature that it was considered justifiable to refer them all to the proper Divisions of the Standards Committee for consideration at the next meetings held.

The complete vote on all the recommendations balloted upon is recorded in the accompanying tabulation. The first column is the number of affirmative votes cast; the second column, the number of negative votes; and the third column, the number of members who voted neither way. The large number of members casting their votes neither for nor against the recommendations was probably due to the fact that they wished to vote on only two or three subjects and to waive their votes on the other subjects.

The report on Tractor Leather Driving Belts has been withheld from publication in the S.A.E. HANDBOOK, however, because of some differences between the report as formulated by the Leather Belting Exchange and the Society of Automotive Engineers and a similar report developed by the Leather Belting Exchange and the Bureau of Standards. As the need for publishing the report at this time does not seem to be pressing, the Standards Department intends to investigate this matter and a revised report thereon may be expected from the Agricultural Power Equipment Division at the June meeting of the Standards Committee.

Subject	*Yes*	*No*	*Not Voting*
Tractor Leather Driving Belts	126	3	207
Brake-Drums	197	1	138
Passenger Car Front Wheel Hubs	191	5	140
Felloe-Bands	190	0	146
Magnet Wire	146	0	190
Engine Testing-Forms	204	5	127
Flywheel Housings	206	0	130
Engine Support-Arms	203	2	131
Motor-Truck Frames	148	4	184
Transmission Lubrication Oils	188	4	144
Motorboat Engine and Propeller-Shaft Couplings	121	0	215
Specification No. 78 for Aluminum Sheet and Strip	181	0	155
Fuel and Lubrication Tube-Fittings	202	2	132
Propeller-Shaft Flexible-Discs	197	4	135
Aluminum Sheet Sizes	150	0	186
Fotman Loops	152	0	184
Upholstery Leather	146	1	189
Aluminum Molding	151	2	183
Screw-Threads	218	4	114
Dimensional Tolerances	222	0	114
Lead-Acid Storage-Batteries	154	1	181
Balloon Tires	161	4	171
Pneumatic Tires	174	0	162
Pneumatic-Tire Rim-Sections	170	0	166
Solid-Tire Demountable Rims	171	0	165
Deflection and Set Test for Pneumatic-Tire Rims	168	0	168

FEBRUARY DATA SHEETS ISSUED

Standards Approved at Annual Meeting Included in New Edition for Handbook

Forty-nine new and revised data sheets were included in the February issue of sheets for the S.A.E. HANDBOOK, which will be sent to the members early this month. The revised S.A.E. HANDBOOK now contains 572 pp. This is a larger number than the Vol. I binders can conveniently accommodate and consequently it has been found advisable by many members to divide the Handbook into two parts, retaining Sections A to C inclusive in the old binder and putting the remaining sections in a new binder, both binders being marked to indicate the sections that they contain.

Two new sections will be found in the new edition, Section L—Body Standards and Recommended Practices, and Section M—General Standards and Recommended Practices. Section K has been revised and will in the future be restricted to standard nomenclature and tests.

Members should bear in mind that the S.A.E. HANDBOOK is arranged so that in case they are not interested in certain classifications of standards, the respective sections can be removed from the Handbook without destroying its general arrangement. In this way it is often possible for members

interested in a limited range of automotive subjects to keep their Handbooks down to a more convenient size.

COMMITTEE "AGREES" TO DISAGREE

Separate Reports on Heat-Treatment Terms Submitted by the Three Societies

The American Society for Testing Materials, the American Society for Steel Treating and the Society of Automotive Engineers each approved some years ago definitions for certain terms relating to the heat-treatment of steel. These definitions varied considerably. With a view to harmonizing these several sets of definitions a committee was appointed, consisting of representatives of the organizations mentioned. R. M. Bird, formerly of the Bethlehem Steel Co., represented the American Society for Testing Materials; J. E. Halbing, of the Willys-Morrow Co., the American Society for Steel Treating; and H. P. Tiemann, of the Carnegie Steel Co., the Iron and Steel Division of the Society's Standards Committee. After several meetings and considerable correspondence, the members of the committee found it impossible to agree upon a set of definitions meeting the various viewpoints presented. Separate reports were therefore submitted to the societies by the three members of the committee.

The report submitted by Mr. Tiemann to the Iron and Steel Division consists of four parts

Heat-treatment definitions recommended
Other definitions submitted for purposes of comparison
Statement consisting of an introductory discussion, followed by comments, criticisms and comparisons of the various definitions
Correspondence of interest

The definitions proposed by Mr. Tiemann and submitted to the members of the Iron and Steel Division for approval, in place of those now printed in the S.A.E. HANDBOOK, p. D11, are given in full hereinafter.

HEAT-TREATMENT DEFINITIONS

Heat-Treatment.—The change, or the series of changes, in temperature, and also the rate of change from one temperature to another, brought about to secure certain desired conditions or properties in a substance.

Annealing.—A form of heat-treatment for the purpose of softening, or relieving strains, or both.

(1) *Annealing with Grain Refinement.*—Heating to a temperature above the critical range for hypereutectoid or euctectoid steels or above the lower limit of the range for hypereutectoid steels followed by relatively slow cooling through that range

Note.—This does not give as fine a grain as quenching

(2) *Normalizing.*—Heating to a temperature above the critical range to secure more uniform distribution of the structural constituents, followed by relatively slow cooling through that range in still air at room temperature

Note.—This term is generally restricted to such treatment as applied to hypereutectoid steels

(3) *Spheroidizing.*—Prolonged heating at a temperature slightly below the critical range to produce coagulation of the cementite into globules, usually followed by relatively slow cooling

(4) *For Softening or Relieving Strains.*—Heating to a temperature not necessarily sufficient to refine the grain, followed by relatively slow cooling if necessary

(5) *Drawing.*—Reheating, after quenching, to some temperature below the critical range, followed by any permissible rate of cooling

Note.—The use of this term to indicate heating without previous quenching should be avoided; the term *annealing* should be employed in such a case

(6) *Tempering.*—Reheating, after hardening by quenching, to some temperature considerably below the critical range, followed by any permissible rate of cooling

Notes.—Drawing and tempering are practically synonymous in commercial practice

By "critical range" is meant the A_c range on heating and the A_r range on cooling. In view of the different applications of the term *annealing*, it is recommended that the specific treatment intended be stated unless clearly indicated.

Quenching.—Rapid cooling.

Quenching for Hardening.—Rapid cooling, through the critical range, to a temperature not exceeding that which subsequently may be employed for drawing or tempering.

Carburizing by Cementation.—Adding carbon to steel or wrought iron by heating the metal below its melting-point in contact with carbonaceous material.

Note.—The term "carbonizing" used in this sense is undesirable and should be avoided.

Case-Hardening. — Carburizing, and subsequently hardening by suitable heat-treatment, the outer portion of an object.

Case.—The outer, carburized portion of a case-hardened object.

Core.—The inner, uncarburized portion of a case-hardened object.

Cyaniding.—A method of surface hardening whereby the object, or a portion of it, is heated and brought into contact with a cyanide salt, followed by suitable heat-treatment.

The principal causes for differences of opinion among the members of the committee may probably be traced to certain proposed conditions, according to Mr. Tiemann.

That the definitions should be based on methods employed and not on purposes to be accomplished
Restricting a general term to a single specific application
Presenting a restricted definition as though it were general
Not recognizing as heat-treatment any operation directly connected with mechanical working.

Mr. Tiemann believes that "heat-treatment" in its restricted sense may be considered as the application of heat to secure changes in the condition or the structure of a metal or alloy without intentional change in the ultimate, as distinguished from the proximate composition. This definition would accordingly exclude such operations as carburizing or cementation and "annealing" to produce malleable castings, in which cases the ultimate composition is deliberately altered. "Carburizing" has been included in these terms because it is a requisite antecedent to "case-hardening." The scope indicated by this definition for heat-treatment embraces operations having three distinct purposes or objects.

Annealing—softening and relieving strains
Hardening
Regulation of grain size.

"Any single operation of heat-treatment, according to its primary object, can be assigned to one of these main divisions."

The complete report submitted by Mr. Tiemann has been sent to the members of the Iron and Steel Division in mimeograph form and copies may be obtained from the Society by members interested in making a comparative study of the definitions now under consideration by the American Society for Steel Treating, the American Society for Testing Mate-

rials and the Iron and Steel Division of the Standards Committee.

HEAD-LAMPS NOT DESIGNED FOR SERVICE

Motor-Vehicle Administrators Discuss Standardization

That car builders demand the lowest-priced lighting equipment obtainable and, as a consequence, the lamp manufacturers cannot design head-lamps capable of standing up in normal service was brought out at a joint meeting of the Lighting Committee of the Eastern Conference of Motor-Vehicle Administrators and the members of the Lighting Division of the Standards Committee. The motor-vehicle administrators at the meeting were A. W. Devine, of Massachusetts; R. J. Howard, of the New York Motor-Vehicle Bureau; W. W. Matthews, of the Pennsylvania State Highway Department; H. M. Lucius, of the Maryland State Board of Motor-Vehicle Inspection, and M. D. Rudd, of the Connecticut Motor-Vehicle Department. The object of the joint meeting was to determine how the committees could cooperate to the greatest advantage in developing proper standards for automobile lighting apparatus.

As chairman of the Lighting Committee, Mr. Devine stated that the greatest difficulty the administrators experience is the indifference of the car-owners to keeping their head-lamps in good mechanical condition and in proper adjustment, re-adjustments being necessary every 2 or 3 weeks. He emphasized the fact that the reason for this condition is, in many cases, poor material and workmanship, the greatest troubles being due to misformed reflectors, sagging and misplaced lamp filaments and loose lamp sockets.

Mr. Devine stated that his Committee and the Conference of Motor-Vehicle Administrators are extremely interested in proper standards and desire to work closely with the Society of Automotive Engineers in the formulation of lighting equipment standards. It was his opinion that if the car builders would not use such standards as were formulated to meet the engineering and legal requirements, laws would be enacted in the several States that would require inspection and approval of the entire car-lighting equipment.

During the general discussion of head-lamp construction it was brought out that one of the greatest troubles encountered is the design of head-lamp doors, difficulty being experienced in removing them to adjust the lamps and the lenses. The lack of uniformity of contour and variations in the fixed focal-point of the reflectors were also criticized. It was suggested that a standard template be adopted by the Society. It was thought that the standards might well be extended to include the thickness of the metal used in reflectors and also the material itself. The present standards for sockets and connectors were criticized as being too light for use on motor vehicles, especially motor trucks and motorcoaches, many of the existing types being so poor that the voltage-drop is altogether too great. It was suggested that in view of the improvement in bulb construction the present S. A. E. Standard tolerances for the size and the location of the filaments could be reduced to possibly half their present values. R. N. Falge, of the General Electric Co., stated that lamps are already being made with greatly reduced tolerances and that it would be possible to use single-focus lamp bulbs entirely.

These subjects, together with others discussed during the meeting, were referred to Subdivisions, on which several of the motor-vehicle administrators present agreed to serve, for the development of preliminary reports. A meeting of the Lighting Division is planned for the latter part of April to consider these reports.

COACH NOMENCLATURE PROPOSED

Society Motorcoach Committee and Electric Railway Equipment Subcommittee

Believing that it is desirable to establish definite nomenclature for the various types of motorcoach now being operated, the following nomenclature was favored at a joint meeting held in Pittsburgh on March 17 of the Equipment Subcommittee of the American Electric Railway Association and the Society's Motorcoach Committee.

MOTORCOACHES

City Type

(1) Single-deck, having cross or longitudinal seats
(2) Double-deck, having cross or longitudinal seats

Intercity Type

(1) Sedan, having multiple side-doors and full-width cross-seats
(2) Aisle, having front and emergency doors and cross-seats
(3) Chair, having front and emergency doors and movable individual chairs

The nomenclature proposed is intentionally limited to the fundamental types and their principal characteristics, as it is not considered desirable to indicate the modifications that will be used as a result of special conditions. This policy is similar to that followed by the Passenger-Car Body Division in its report on Body Nomenclature.

As a result of a general discussion of the possibilities of standardization in the motorcoach field, it was decided that the Standards Department should make surveys of present practice with respect to the following dimensions which it is believed should receive careful consideration:

Size of Doorway
Overall Width of Body
Minimum Inside Height of Body
Width of Tread
Distance from Center to Center of Springs
Location and Size of Emergency Door
Distance from Dash to Center of Rear Axle

These surveys are to be classified according to the following coach capacities: For single-deck types, up to 18 passengers, 21, 25 and 29 passengers; for double-deck types, up to 64 passengers.

SPRING NOMENCLATURE PROPOSED

Present Standards in Section H of Handbook Reviewed at Division Meeting

The first meeting of the Springs Division since early in 1922 was held on March 21 in Detroit. At this meeting the present standards in Section H of the S.A.E. HANDBOOK were carefully reviewed because of certain criticisms that had been submitted to the Society, and that were found to be satisfactory, only slight revisions being found necessary to bring them into accordance with the best spring practice.

The criticisms considered were submitted to the Society as a result of a general inquiry that had been sent to all spring users as to whether or not the present standards were satisfactory. The Division decided, however, that the present standard for Spring Offsets and Resulting Ends was not in accordance with present practice and as such springs must be designed for each individual application, the Division recommended the elimination of this standard. The fact that the present standard revised to conform with present practice would be of little value also influenced the Division in its action.

The specifications for springs on pp. H10 to H19 inclusive were carefully reviewed and it was decided that the standard should be revised by the elimination of all matter pertaining to dimensional spring data, thus limiting the standard to the testing of springs. It was thought that these tests should be based on the information contained in the present standard and the definitions proposed for approval as S. A. E. Standard. C. P. Hess of the Detroit Steel Products Co. was appointed a Subdivision of one to submit a report covering the revisions proposed. It was considered that specification sheets covering the data eliminated should be prepared and issued by the spring manufacturers.

The original nomenclature recommendation of the Springs Division, which was referred back to the Springs Division at

the June, 1922, meeting of the Standards Committee, was reviewed. These definitions were considered of particular interest at this time, owing to the evolution now taking place in spring design. It is felt that concise definitions, particularly with regard to measuring springs, are needed to clarify many of the terms in common use. The original report of the Division was therefore revised where necessary. The revised report is given hereinafter. It was felt that other than the conventional types, such as springs mounted in rubber shackles, are not used extensively enough to warrant special definitions. The definitions proposed are to be submitted to springs manufacturers and users for comment before final action is taken by the Division.

PROPOSED STANDARD LEAF-SPRING DEFINITIONS

The following definitions are intended primarily to apply to the conventional semi-elliptic type of automobile springs, but should be used where they may apply to unconventional types. All tests or inspection measurements shall be made after rapping in their test or inspection position.

Load.—The number of pounds to be carried by the spring. The *Rated Load* is the number of pounds to be carried by the spring at a given spring height and includes the body, passengers and normal pay-load for which the vehicle is designed.

Unsprung Weight.—The total weight of all parts not supported on the springs, including springs, axles, wheels, rims, tires, etc.

Spring Height.—The normal distance from a line through the centers of the spring-eyes to the face of the spring seat at its center. The *Load Height* is measured with the spring under its rated load.

Clearance.—The maximum distance the spring can deflect from a given position. The *Load Clearance* is measured from the rated load position of the spring.

Opening.—The normal distance from a line through the centers of the spring-eyes to the face of the main leaf in line with the center of the spring seat.

Length.—The distance between the centers of the spring-eyes. The *Load Length* is measured with the spring under the rated load.

Flexibility.—The number of pounds required to deflect the spring 1 in. measured over the range of from 75 to 125 per cent of the rated load.

Deflection.—The travel in inches of the spring under the application of a specified load in pounds.

In Chairman Whitten's opinion one of the most beneficial standards that the Division could sponsor would be for the dimensions of leaf-spring stock because of the unnecessary variety of stock sizes used at the present time. It was noted that although this subject is covered by the present S. A. E. Standard for Leaf-Spring Steel, p. D99 of the S.A.E. HANDBOOK, the standard is limited to the rolling tolerances. S. P. Hess was appointed a Subdivision of one to submit a tentative recommendation covering this subject at the next meeting of the Division.

The Division members present at the meeting, which was held in the rooms of the Old Colony Club in the Hotel Tuller, were F. A. Whitten of the G. M. C. Truck Co., A. H. Remsen of the Rickenbacker Motor Car Co., W. E. Dunston of the C. G. Spring & Bumper Co. and S. P. Hess of the Detroit Steel Products Co. It is expected that there will be another meeting of the Division early in May, at which final action will be taken on the various recommendations. Comments and constructive criticisms of the proposed definitions submitted to the Society during April will receive consideration at this meeting.

PASSENGER-CAR BODY DIVISION MEETS

Representatives of body hardware manufacturers met with the members of the Passenger-Car Body Division in Detroit on March 20 for a general discussion of the standardization of body hardware. Several recommendations, based on proposals submitted by the Automobile Body Builders' Association's committee on standardization were tentatively approved, but will be submitted to body and hardware manufacturers for approval prior to final action by the Division. These recommendations covered door hinges of the strap type, hinge nomenclature and door locks.

STANDARD BUMPER HEIGHTS REDUCED

Parts and Fittings Division Revises Present S. A. E. Standard for Bumper Mountings

Ths present standard for Automobile Bumper Mountings, p. C55 of the S.A.E. HANDBOOK, was revised by the Parts and Fittings Division on March 18 to specify 20 and 21 in. for the heights of the front and the rear bumpers respectively, instead of the present heights of 21 and 22 in. This action was based on a survey of the present practice of manufacturers of including bumpers as regular equipment. The complete standard, revised as proposed by the Division, is given below.

PROPOSED STANDARD ON BUMPER DIMENSIONS

Protective bumpers for the front and rear of passenger cars, small motorcoaches and light delivery trucks shall conform to the following dimensions:

The horizontal center-line of the bumper face exclusive of fittings shall be 20 in. plus or minus ⅜ in. per in. of effective face above the ground for front bumpers and 21 in. plus or minus ⅜ in. per in. of effective face above the ground for rear bumpers.

The overall length of front and rear bumpers shall be 59 to 60 in.

The face of front and rear bumpers shall be flat.

The minimum vertical depth of individual bars in front and rear bumpers shall be 2 in.

In amplification of this report, it was stated that the bumper heights should be measured with the vehicle supplied with a normal amount of water, oil and gasoline, but without passengers or other load, and that the vertical spread of the bumper face shall be the distance between the upper and the lower edges of the outer elements exclusive of any projecting parts.

The present overall length of bumpers was retained because the bumper manufacturers considered that these standard lengths tended to prevent the purchase of bumpers of shorter lengths, which would make them ineffective. The recommendation will be submitted to the Standards Committee at the Summer Meeting and, if approved by the Society, will be combined with the present standard for bumper mountings, now printed on p. H24 of the S.A.E. HANDBOOK, which specifies the proper punching for the front frame horns.

SHOCK-ABSORBER MOUNTINGS

The feasibility and possibility of standardizing shock-absorber mountings were considered at the March meeting of the Parts and Fittings Division. Although it was realized that such standardization would be very difficult to accomplish, F. G. Whittington of the Stewart-Warner Speedometer Corporation was appointed a Subdivision of one to study the situation. This subject was considered by the Division as a result of a paper presented at the February meeting of the New England Section by E. A. Adams of the Lovejoy Mfg. Co., in which he stated in part:

> We have presented a little idea of the difficulties of shock-absorber design and application. We believe that the last part of this problem is one that could well be referred to the S. A. E. Standards Committee for consideration. Surely some common ground exists where the various shock-absorber and car manufacturers can meet and develop methods of application that would very materially decrease the ultimate cost to the car-owners.

Vol. XIV April, 1924 No. 4

Intake-Manifold Distribution

By H. W. Asire[1]

Indiana Section Paper *Illustrated with* Drawings and Photographs

DEFINITE knowledge as to the behavior of gases and liquids in the manifold of an internal-combustion engine being lacking, an attempt is made to answer the questions: (*a*) How bad is the distribution, (*b*) how do the different types of manifold compare, (*c*) why is the liquid distribution in some manifolds poor and (*d*) how shall we proceed to correct the trouble? The solution of the problem is affected by the facts that, in extremely cold weather, nearly all fuel is delivered to the engine, at the time of starting, as a liquid; that all cars perform poorly under such conditions, some engines, when cold, "hitting" on only one or two cylinders; and that, because of inferior distribution, many multi-cylinder engines are outperformed by single-cylinder engines of similar design.

In earlier days when the fuel was vaporized to a greater extent the distribution of it was easy, but as fuels have continually become heavier and portions of liquid are carried over in increasing amounts, the problem has become one of distributing liquid. Two solutions presented themselves: (*a*) the fuel might be vaporized before a division of the mixture stream occurred, or (*b*) means might be provided for dividing the mixture stream properly. It was found that fuels vaporized before distribution are more sensitive to knock, owing to the high temperature necessary to produce vaporization, whereas cold mixtures allow higher compression-pressures and greater economy of operation.

Heretofore, exhaust-gas analysis has been commonly employed to determine accurately the distribution of fuel, but this method requires great skill, and leaks may completely change the result; such analyses repeated a large number of times become very laborious and consequently are not widely used. The method usually employed is to observe the color of the flame given off from the exhaust-port.

By means of a specially constructed dummy engine, from which the crankshaft, the connecting-rods and the pistons had been removed, and having separators connected to the bottom of each cylinder, results extremely close to normal were obtained. A large number of tests could be performed in a short time and the cold fuel tests were interpreted under "hot-engine" conditions.

The three most important causes of improper distribution are said to be (*a*) the stratification of the liquid with respect to air, (*b*) puddles of liquid forming in the manifold in dead-air pockets and (*c*) the effect of the firing order. Stratification is produced by the difference in the weight of the liquid and the air and the tendency of the liquid, after having velocity imparted to it by the air, to continue in the same direction and impinge on the wall of the manifold at the turn. Photographs of the formation of dead-air pockets were obtained by depositing ammonium chloride smoke on black paper. Under conditions of steady or uniformly pulsing air-flow the puddles in the air-pockets remain practically constant in size, but these conditions seldom occur.

The tests made covered many combinations of stratification and puddle formation, a disturbing factor being the variability of the flow of air due to the varying degrees of turbulence set up by uneven surfaces, sharp corners, the position and the shape of the throttle, tortuous bends and other causes difficult to analyze.

The manifolds tested included one of the hot-spot type, a four-cylinder square transparent manifold, an inverted ramshorn-type manifold, another one similar to it made of glass and a six-cylinder manifold.

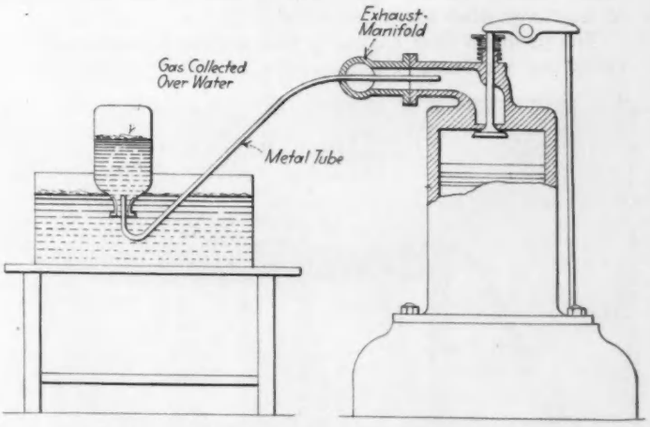


Fig. 1—Method of Taking Exhaust-Gas Samples

To Secure a Sample the Metal Tube Is Attached to the Exhaust-Manifold in Such a Way That It Projects into the Port Almost to the Valve. The Other End of the Tube Is Submerged in Water and Permits the Sample To Be Collected in an Inverted Bottle That Has Been Previously Filled with Water. A Separate Tube Is Required for Each Exhaust-Port

THE distribution problem has been brought into prominence because of the absence of definite knowledge of the behavior of gases and liquids in manifolds. No quantitative figures are given in the literature on the subject. The solution of the problem vitally affects the following conditions:

(1) Nearly all fuel is delivered as a liquid when starting an engine in extremely cold weather

(2) Under these cold conditions, all cars perform poorly

(3) Some engines, when starting cold, hit on only one or two cylinders

(4) It is usually found that single-cylinder engines outperform multi-cylinder engines of similar design; and this is usually attributed to the inferior distribution of multi-cylinder engines. Just what part of this inferior performance is to be attributed to poor liquid distribution in the intake manifold?

This investigation attempts to answer the following questions:

(1) How bad is the distribution about which we complain

(2) How do different types of manifold compare?

(3) Why is the liquid distribution in some manifolds poor?

(4) How shall we proceed to correct the trouble?

The use of manifolds to distribute fuel from a carbureter to the various cylinders of a multi-cylinder

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engine was a simple problem so long as the fuels employed vaporized to a large degree. With the advent of the heavier fuels, however, portions of liquid were carried through the manifold. At present less than one-half the liquid delivered by the carbureter is vaporized by the time it reaches the first dividing-point, even at an atmospheric temperature of 70 deg. fahr. This condition exists with the present commercial grades of gasoline on all manifolds during starting and to a lesser degree during operation, depending on the amount of heat supplied to the manifold.

The problem that formerly was merely a matter of distributing gas now becomes one of distributing liquid,

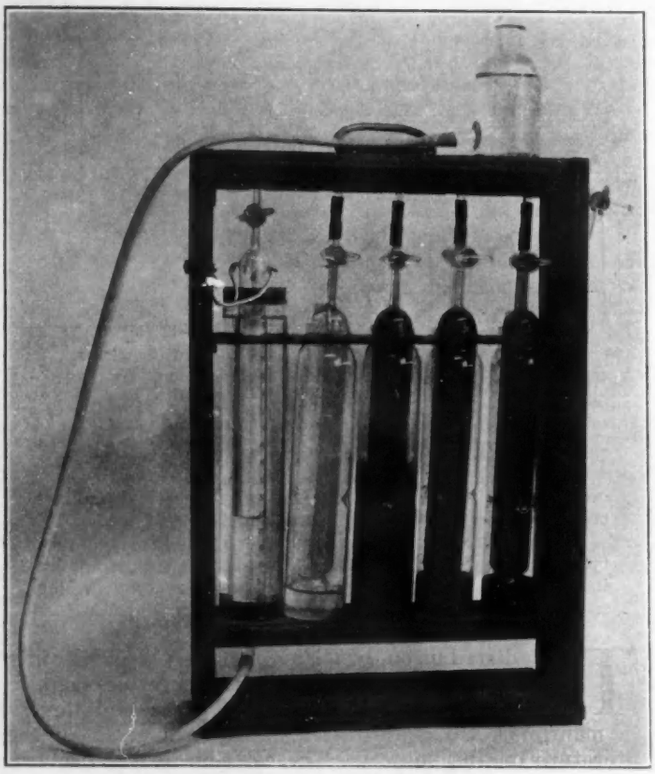

FIG. 2—APPARATUS USED TO DETERMINE THE PERCENTAGES OF CARBON MONOXIDE, CARBON DIOXIDE AND OXYGEN IN THE EXHAUST-GAS SAMPLE

The Tube at the Left Is the Measuring Tube in Which the Sample of Exhaust Gas Is Placed. The Second Tube Contains Potassium Hydroxide for Absorbing Carbon Dioxide. In the Next Tube Is a Solution of Potassium Hydroxide to Which a Small Quantity of Pyrogallic Acid Has Been Added; the Function of This Tube Is the Absorption of the Oxygen. The Two Remaining Bottles Are Filled with Cuprous Chloride and Are Used To Absorb the Carbon Monoxide; Two Bottles Are Filled with the Chloride when Analyzing Exhaust Gases To Prolong the Life of the Solution

since improper distribution of liquid means improper functioning of the engine. The problem can be solved in either of two ways. The fuel may be vaporized before a division of the mixture stream occurs, or means may be provided for dividing the mixture stream properly. It is generally admitted that a gas supplied to a manifold when no liquid is present distributes reasonably well with very little variation between cylinders. Exhaust-gas analysis tests, which will be described later, support this conclusion.

If the fuel is vaporized before distribution, the resulting mixture-temperatures are high and as a result the engine becomes more sensitive to fuel knock than if the mixture had been introduced cold. The use of cold mixtures allows higher compression-pressures and greater economy of operation.

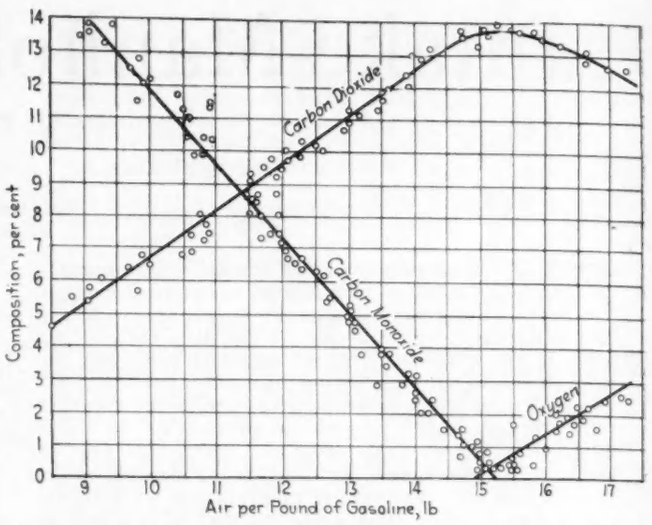

FIG. 3—CURVES FOR CONVERTING THE PERCENTAGES OF CARBON DIOXIDE, CARBON MONOXIDE AND OXYGEN IN A SAMPLE OF EXHAUST GAS INTO TERMS OF MIXTURE-RATIO

These Curves Were Made from Data Taken by the Bureau of Mines from Laboratory Tests on a Multi-Cylinder Engine. The Samples Were Taken in the Exhaust Pipe about 3 Ft. from the Valves

METHODS OF MEASURING DISTRIBUTION

The most common method heretofore employed for accurately measuring the distribution of fuel to the cylinders was exhaust-gas analysis. By this means a sample of exhaust gas, secured at the exhaust-port, is analyzed and the quantities of oxygen, carbon monoxide and carbon dioxide are ascertained. These figures indicate whether the mixture before burning was lean or rich, and by referring to calibration curves the actual mixture-ratios may be obtained.

Considerable skill is required to make and interpret exhaust-gas analyses. Air-leaks at the joints of the apparatus or between the exhaust or the intake manifold and the cylinder-block may completely change the

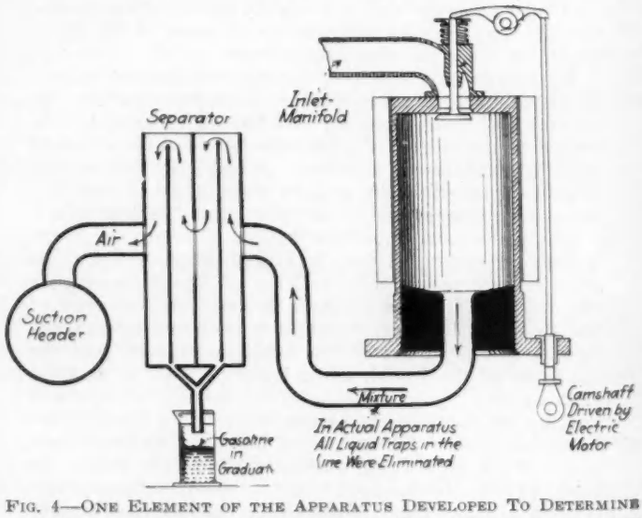

FIG. 4—ONE ELEMENT OF THE APPARATUS DEVELOPED TO DETERMINE THE AMOUNT OF LIQUID DELIVERED TO EACH CYLINDER WITHOUT ACTUALLY OPERATING AN ENGINE

An Engine from Which the Crankshaft, the Connecting-Rods and the Pistons Had Been Removed Had a 2-In. Pipe Connection Made at the Bottom of Each Cylinder. This Pipe Led to a Separator One for Each Cylinder, and Then to a Common Header That Was Connected to a Suction Line. The Separator, as Its Name Indicates, Extracted the Liquid from the Fuel Stream and Delivered This Liquid to a Graduate Underneath. The Suction Demand, While Constant on All the Cylinders, Was Only Admitted to the Manifold when the Intake-Valves, Which Were Operated in the Normal Way by the Camshaft That in Turn Was Revolved by an Adjustable-Speed Electric Motor, Were Open

results. During one test an unobserved leak between the exhaust-manifold and the cylinder-block caused oxygen to be present in quantities of between 2 and 3 per cent. To sample the exhaust gas, a tube is sealed into the exhaust-manifold in such a manner that it

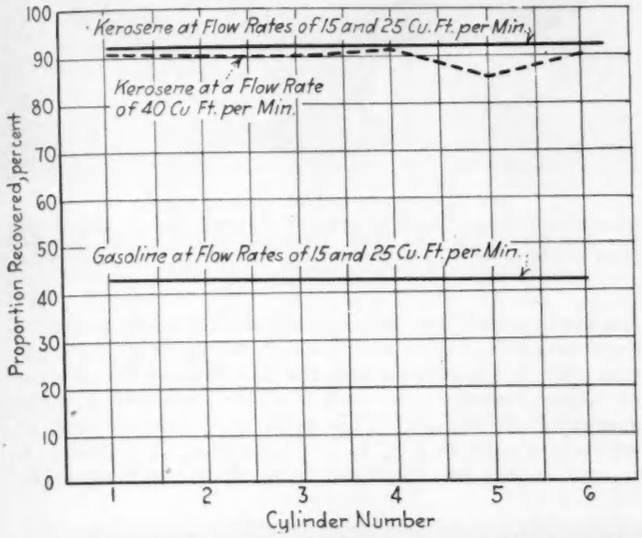

FIG. 6—CHART SHOWING THE EFFICIENCY OF THE SEPARATORS USED ON THE SIX-CYLINDER TEST MACHINE

The High Efficiency of These Separators Can Be Seen from the Results Obtained, More than 90 Per Cent of the Kerosene Contained in the Mixture Stream Being Recovered at a Room Temperature of 90 Deg. Fahr. from a Mixture-Ratio of Approximately 13 to 1. When Gasoline Was Used Less Was Collected, Because Nearly Half of It Vaporized before Reaching the Separators. At a Room Temperature of 75 Deg. Fahr., Less Vaporization Occurred and 56 Per Cent of the Gasoline Can Be Recovered

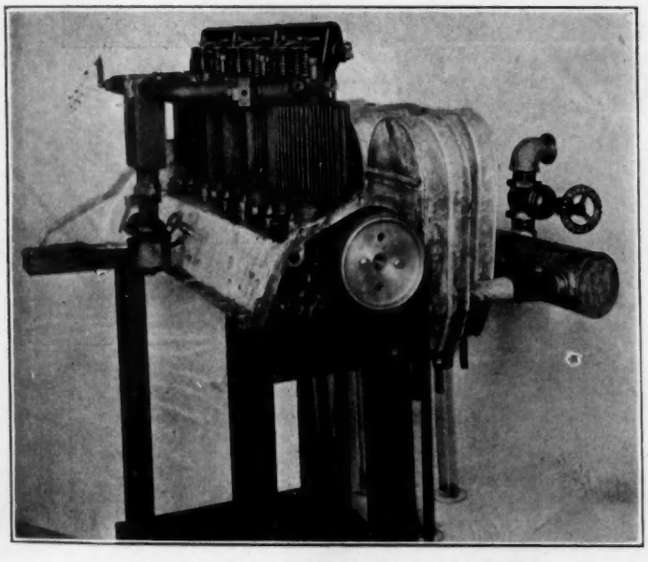

FIG. 5—THE SIX-CYLINDER TEST MACHINE

While This Machine Did Not Duplicate Exactly the Conditions Found in an Engine Running under Its Own Power, the Results Obtained, as Indicated by Many Tests, Were Extremely Close to Normal Conditions. With This Machine a Large Number of Tests Can Be Run in a Very Short Time and as a Result an Experimental Manifold Can Be Built Up from Sheet Metal, Tested and Thrown Away Before a Cast-Iron Manifold Can Be Procured from the Foundry

projects into the port nearly to the valve. This set-up is illustrated in Fig. 1. The other end of the tube is submerged in water and allows the sample to be collected in an inverted bottle that has previously been filled with water. A separate tube is used, leading into each exhaust-port. In the case of a four-cylinder engine four

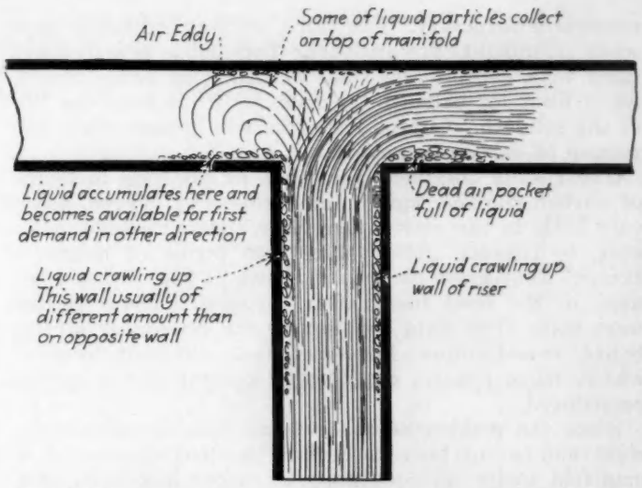
Air Eddy
Some of liquid particles collect on top of manifold
Liquid accumulates here and becomes available for first demand in other direction
Dead air pocket full of liquid
Liquid crawling up This wall usually of different amount than on opposite wall
Liquid crawling up wall of riser

FIG. 7—TYPICAL CONDITIONS AT THE MANIFOLD TEE WITH FULL THROTTLE

The Way in Which the Liquid Fuel-Particles Cling to Portions of the Wall and Crawl along It and Their Disinclination To Change Their Direction at a Turn Are Clearly Brought Out

tubes are employed and four bottles are used to contain the gas samples taken during one engine-run.

Analysis of the gas sample is usually made on an apparatus shown in Fig. 2. The four tubes shown at the right of the measuring tube each contain about 150 cc. of different solutions. The first contains potassium hydroxide, which will absorb about 40 volumes of carbon dioxide before renewal is necessary. The second bottle contains potassium hydroxide to which has been added a small amount of pyrogallic acid. This solution will absorb about two volumes of oxygen before

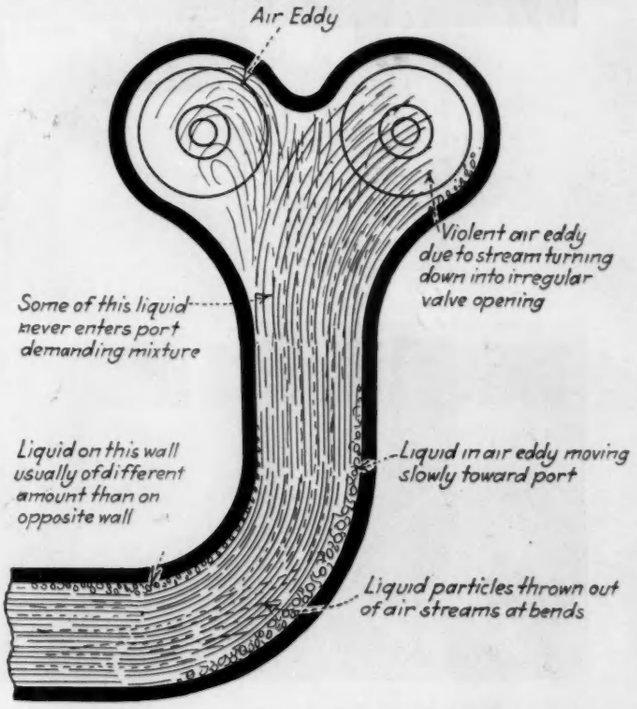
Air Eddy
Violent air eddy due to stream turning down into irregular valve opening
Some of this liquid never enters port demanding mixture
Liquid on this wall usually of different amount than on opposite wall
Liquid in air eddy moving slowly toward port
Liquid particles thrown out of air streams at bends

FIG. 8—TYPICAL CONDITIONS IN THE CYLINDER-HEAD AT FULL THROTTLE

This Drawing Shows Plainly That Although the Fuel and the Air Are Thoroughly Mixed when They Leave the Carbureter, This Condition Does Not Exist after the First Bend Is Reached. If the Mixture Stream Should Attempt To Enter the Valve on the Right and the Heavier Portions of the Fuel Were on the Left Side of the Manifold, This Fuel Would Never Find Its Way through the Valve Demanding This Charge

renewal is necessary. The third bottle is ordinarily used when illuminants are analyzed. This bottle is sometimes filled with cuprous chloride, the same as bottle No. 4, when used for exhaust-gas analysis to prolong the life of the solution. Cuprous chloride will absorb about one volume of carbon monoxide.

The results obtained from such an analysis in terms of carbon dioxide, carbon monoxide and oxygen mean very little to the average engineer. It is possible, however, to convert these values into terms of mixture-ratios. Conversion curves are shown in Fig. 3 that were used in the tests hereinafter reported. These curves were made from data supplied by the Bureau of Mines. Other investigators have reported different results, which, when plotted, conform in general to the curves reproduced.

Since the making of exhaust-gas analyses on a sufficient number of tests to outline the performance of a manifold under all conditions is rather laborious, this method of distribution measurement is not widely used. Distribution is commonly measured by observing the color of the flame given off from the exhaust-port. Skilful observers can tell the degree of richness or leanness accurately. Both the analysis and the color tests are usually run in laboratories or dynamometer rooms where the engines are very hot and the distribution caused by these temperatures is very good. During this investigation a method was developed for determining the amount of liquid delivered to each cylinder without actually operating an engine. This apparatus, one element of which is shown in Fig. 4, is constructed as follows: A dummy engine was employed from which the crankshaft,

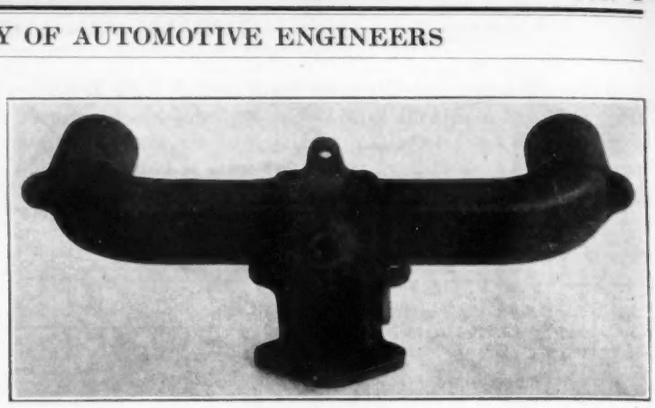

FIG. 10—ONE OF THE MANIFOLDS TESTED

This Four-Cylinder Manifold Was of the Hot-Spot Type with the Hot-Spot Located on the Riser. This Hot-Spot Provided Sufficient Heat To Vaporize a Large Part of the Fuel before Any Distribution Occurred

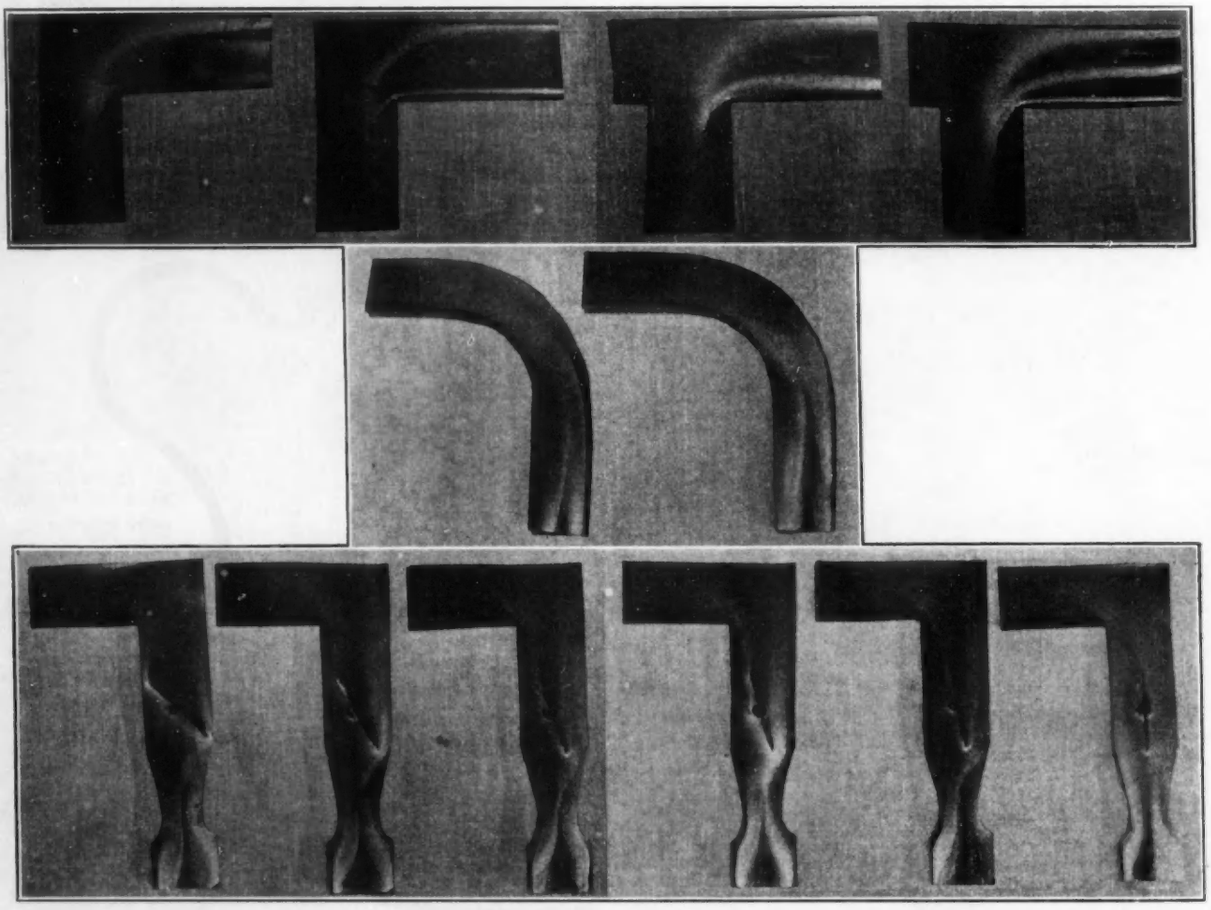

FIG. 9—HOW DEAD AIR-POCKETS ARE FORMED IN MANIFOLDS AT POINTS WHERE THE AIR CHANGES DIRECTION

These Photographs Were Obtained by Depositing Ammonium Chloride Smoke on Black Paper. This Smoke, Which Was Formed by Mixing Ammonia and Hydrochloric Acid Fumes at a Point in the Air-Stream, Was Led to the Desired Point in Two Small Tubes, the Pressure Being Barely Sufficient To Cause It To Issue into the Air-Stream. The Smoke Was Then Led by the Air, Which Wiped the Paper Paralleling Its Course, and Enough of the Particles Were Deposited To Give the Effect Shown. Puddles of Liquid Form in the Air Pockets and Remain More or Less Constant in Size While the Air Flow Is Steady or Uniformly Pulsing. The Two Upper Views Are of a Square Bend in a Manifold of Square Cross-Section at Flow Rates of 60 Cu. Ft. per Min. at the Left and 100 Cu. Ft. at the Right; the Central View Shows the Air Flow through Round Bends in a Square-Section Manifold, While the Two Views at the Bottom Are Reproductions of Photographs of the Air Flow through the Venturi and the Throttle

the connecting-rods and the pistons had been removed. A 2-in. pipe connection was made at the bottom of each cylinder. This pipe led to a separator and then to a common header, which was attached to a suction line. The separator extracted the liquid from the fuel stream, collected it and delivered it to a graduate suspended beneath. In the case of a four-cylinder engine, four separators were employed, each catching the liquid delivered to a particular cylinder. The suction demand, while constant on all the cylinders, was only admitted to the manifold when the intake-valves were open. These valves were operated in the normal way by the camshaft, which in turn was revolved by a variable-speed electric motor.

To this machine could be attached any manifold, standard or experimental, for test. A photograph of the six-cylinder test-machine appears in Fig. 5. Though this machine did not duplicate exactly the conditions found in an engine actually running under its own power, the results at least were extremely close to the normal conditions, as was indicated by many tests. It was possible to run a large number of tests with this machine in a very short time, and as a result an experimental manifold could be built up of sheet metal, tested and thrown away before a cast-iron manifold could be obtained from the foundry.

The separators used on this machine were each tested. The results appear in Fig. 6. It will be noted that the

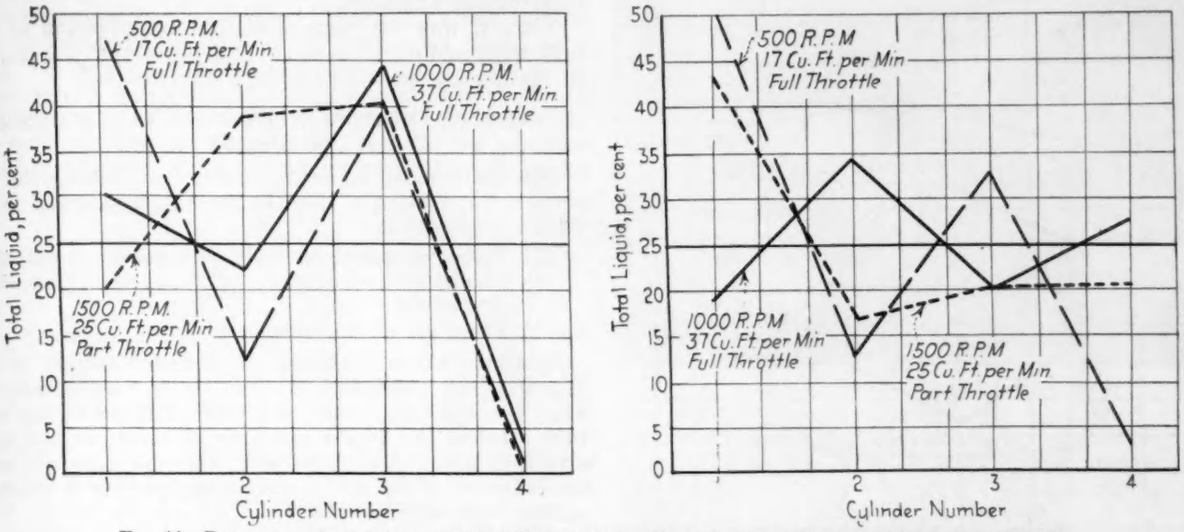

FIG. 11—RESULTS OF LIQUID-DISTRIBUTION TESTS ON THE FOUR-CYLINDER MANIFOLD SHOWN IN FIG. 10

The Two Series of Tests Were Made under the Same Conditions of Speed, Flow Rate and Throttle Opening. The Results Shown at the Right Were Obtained with a Manifold Having Distributing Rings Located in the End of Each Leg. The Difference in the Shape of the Curves, Especially That of the Test at 1500 R.P.M., a Flow Rate of 25 Cu. Ft. per Min. and Part Throttle, Is Marked

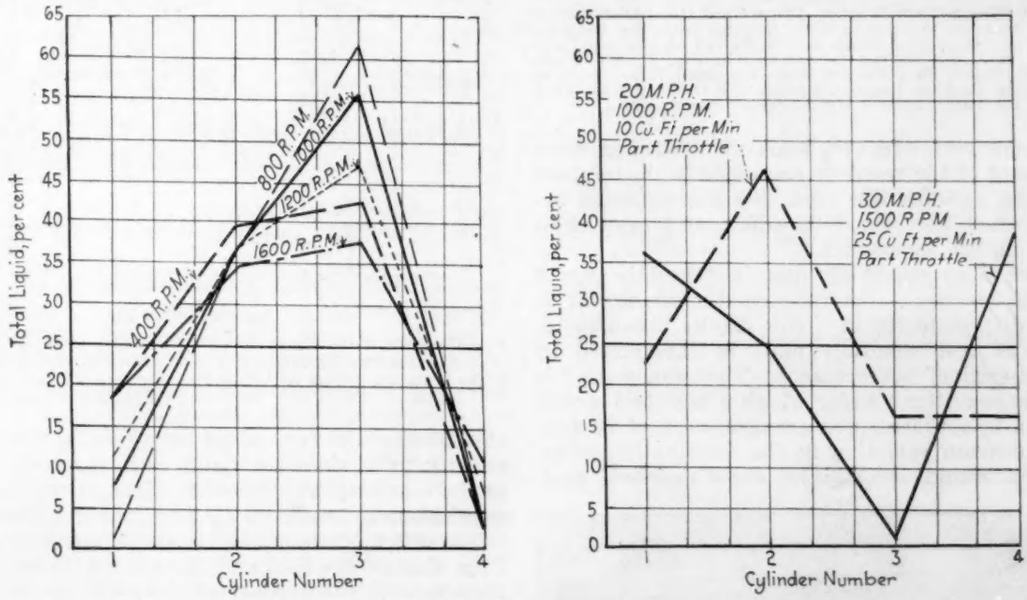

FIG. 12—RESULTS OF ANOTHER SERIES OF LIQUID-DISTRIBUTION TESTS ON A SECOND MANIFOLD OF THE SAME TYPE

The Tests Shown in the Left-Hand Chart Were Made at Full Throttle and Those at the Right at Part Throttle. While the Results Obtained in These Tests Differ from Those Presented in Fig. 11, This Is Attributed to the Erratic Behavior of the Mixture Flow Which Made It Possible To Obtain Several Sets of Performance Curves from the Same Manifold

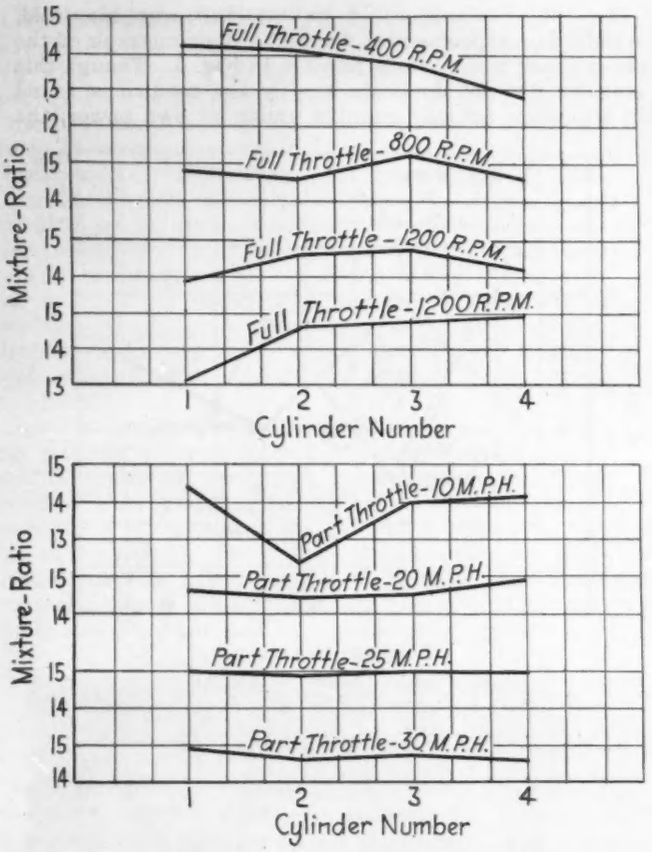

FIG. 13—DISTRIBUTION AS INDICATED BY AN ANALYSIS OF THE EXHAUST GAS FROM A FOUR-CYLINDER ENGINE

These Analyses, Which Were Made to Prove That Good Distribution under Actual Operating Conditions Was Obtained from the Manifold Shown in Fig. 10, Have Been Expressed in Terms of Mixture-Ratio by Using the Conversion Curves Reproduced in Fig. 3. The Tests from Which the Upper Four Curves Were Obtained Were Made at Full Throttle and Various Engine Speeds; the Other Set of Four Were for Part Throttle and Different Car Speeds

separators were very effective, since they collected more than 90 per cent of the kerosene contained in the mixture stream. When gasoline was used, less was collected because of the fact that nearly one-half of it vaporized before reaching the separators.

The cold tests on manifolds described in this report offer a rapid means of determining the ability of a manifold to distribute liquid. The results obtained by this method of test naturally must be interpreted in terms of "hot-engine" performance. They represent the worst possible conditions under which a manifold would be called upon to operate. For example, even at 70 deg. fahr., the maximum variation in the distribution when using gasoline would actually be about one-half that

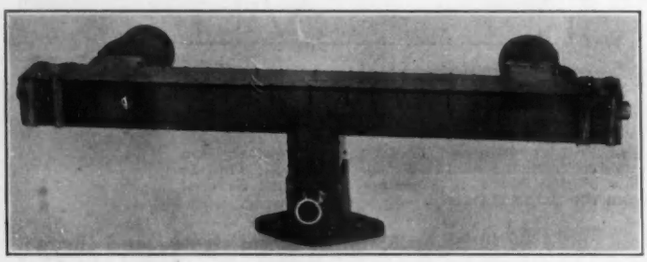

FIG. 14—A FOUR-CYLINDER TRANSPARENT MANIFOLD OF SQUARE CROSS-SECTION

This Manifold Was Made of Celluloid To Permit Complete Observation of the Mixture Flow

shown on the curve sheets. This modification is introduced by the fact that when commercial gasoline passes through an unheated manifold at that temperature, about one-half of it vaporizes. As the manifold rises in temperature, more liquid is vaporized and, as a result, the distribution improves.

Since it was the purpose of this investigation to deal only with cold distribution, it is believed that the manner of testing and plotting the data was justified.

CAUSES OF IMPROPER DISTRIBUTION IN COMMERCIAL MANIFOLDS

The three most important influences causing the improper distribution of fuel in present commercial manifolds apparently are

(1) The stratification of liquid with respect to the air
(2) Puddles of liquid formed in the manifold in dead-air pockets
(3) The effect of the firing order

Stratification is a natural phenomenon caused by the fact that the liquid fuel is many times heavier than the air. Consequently, when any bend is made in the mixture stream, the liquid tends to continue in the same direction that it has previously been pursuing owing to the influence of the air velocity, and as a rule it impinges against the wall of the manifold at the turn. It is

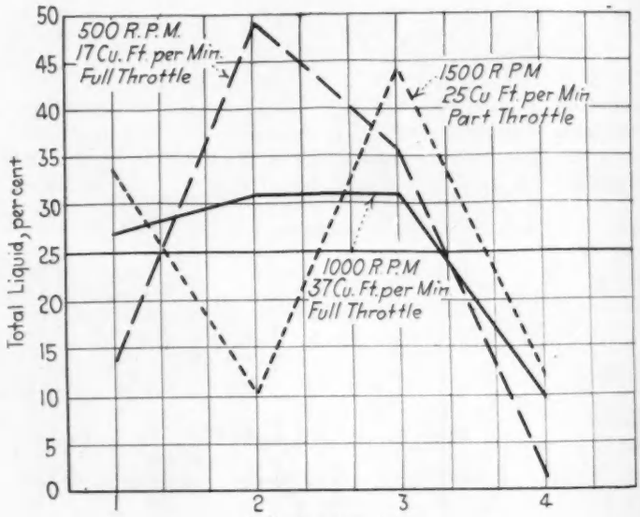

FIG. 15—LIQUID DISTRIBUTION IN A FOUR-CYLINDER ENGINE EQUIPPED WITH THE TRANSPARENT MANIFOLD SHOWN IN FIG. 14

Flow Tests upon This Manifold Did Not Show That the Distribution Was Much Improved over That Secured with the Standard Manifolds

obvious that the fuel moves only because the air imparts velocity to it, since the liquid is in large or small drops as the case may be. Other portions of the liquid stream crawl along the walls of the manifold and adhere to them.

The effect of these conditions is illustrated in Fig. 7. Even though the fuel and the air are thoroughly mixed upon leaving the carbureter, they are no longer in this condition after the first bend has been reached. If this mixture stream should attempt to enter the valve on the right side of the manifold shown in Fig. 8 and the heavier portions of the liquid were upon the left, the fuel would never find its way through the valve demanding this charge.

Numerous tests and observations under conditions of actual flow have demonstrated this phenomenon very conclusively. Conditions may be so extreme that one cylinder will be robbed almost completely of its normal

supply of fuel because of the peculiar stratification of the liquid stream.

It will be noted from the photographs reproduced in Fig. 9 that dead-air pockets are formed in manifolds at points where the air changes direction. To secure these photographs it was necessary to deposit ammonium chloride smoke on black paper. This smoke was formed by mixing ammonia and hydrochloric acid fumes at a point in the air stream. Two small tubes 1/16 in. in diameter led the gases to the desired point under a pressure barely sufficient to cause them to issue into the air stream. The smoke was then led by the air that wiped the paper paralleling its course. Enough smoke

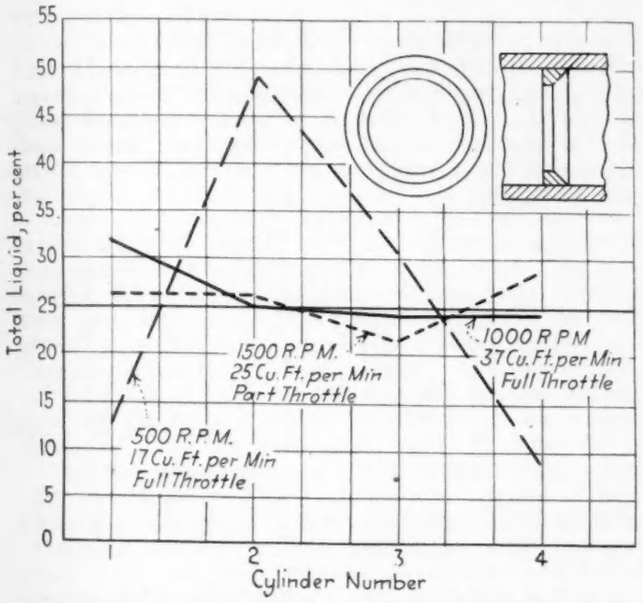

FIG. 16—LIQUID DISTRIBUTION IN A FOUR-CYLINDER ENGINE EQUIPPED WITH A SQUARE TRANSPARENT MANIFOLD HAVING 1/8-IN. SHARP-EDGE DISTRIBUTING RINGS AT THE END OF EACH LEG

Changing the Square Section of the Manifold Shown in Fig. 13 to Round before Reaching the Valves and Using Distributing Rings in Each Leg, as Shown in the Upper Portion, Resulted in a Change of Distribution at the Higher Rates of Flow

particles were deposited on the paper to cause the effect shown. In the air-pockets here shown puddles of liquid were formed. So long as the air-flow is steady or uniformly pulsing, the puddles remain more or less constant in size. In most firing orders, however, this condition of uniform pulsation does not exist. For example, in a four-cylinder engine, having a firing order 1-2-4-3, greater intervals of time exist between 4 and 1 than between 1 and 2. Cylinder No. 1 in addition must change the direction of flow, which formerly was in the direction of No. 4. No. 1 then establishes the flow from the manifold tee to the port. No. 2 following has the advantage that the mixture stream has already been established and as a result merely has to deflect its direction a small amount. If the manifold leg had been perfectly clean and free from liquid when No. 1 started to pull, No. 2 would have received a much greater charge of fuel than No. 1. As is always the case, however, the walls are wet and puddles have formed before No. 1 begins to pull. These puddles have a chance to form on the bottom of the manifold during the interval when Nos. 3 and 4 are receiving their charges. If the manifold walls are swept fairly clean, the puddles will be small. If pockets exist in which liquid can be trapped, the puddles will be larger. Depending upon the size of the puddle, then, No. 1 may be rich or lean.

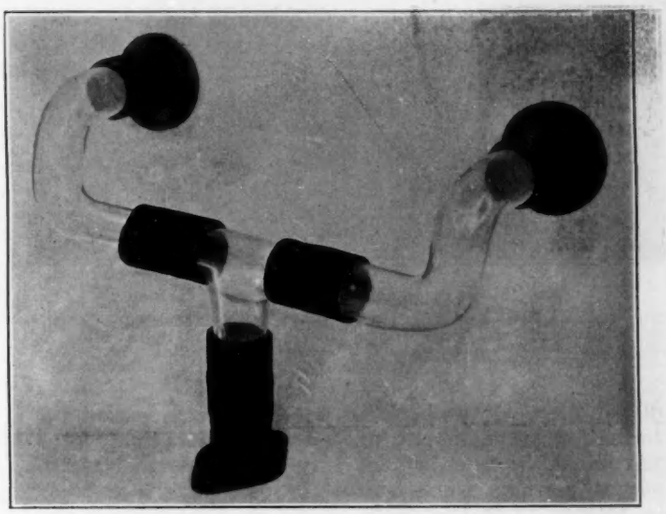

FIG. 17—AN INVERTED RAMSHORN TYPE OF MANIFOLD

This Manifold Was Made Largely from Glass Which Permitted Detailed Observation of the Mixture Flow. The Carbureter Flange Fitting Was Attached by a Piece of Hose, Thus Permitting Rotation of the Flange Which in Turn Allowed Experiments with Throttle Positions in Different Rotational Planes To Be Made. The Outstanding Characteristic of This Manifold Was the Peculiar Way in Which the Fluid Streamers Spiraled Their Way around the Bends. The Character of the Air Flow Was Such as To Cause These Streamers To Change Suddenly from One Path to Another without Any Apparent Reason or Any Mechanical Shifting of the Adjustment

In the tests hereinafter reported a great many combination of the conditions just described existed. It was seldom known to what extent stratification controlled

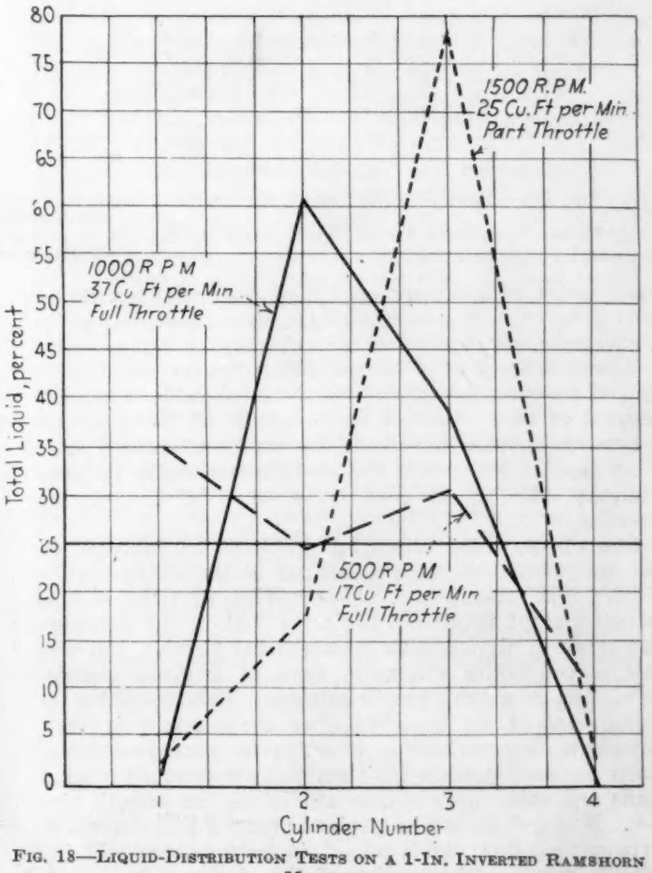

FIG. 18—LIQUID-DISTRIBUTION TESTS ON A 1-IN. INVERTED RAMSHORN MANIFOLD

The Distribution Obtained with this Manifold Was Very Poor as Compared with the Standard and the Square Transparent Manifolds

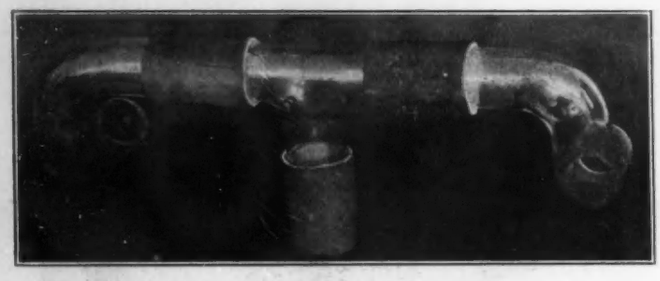

FIG. 19—A TRANSPARENT RAMSHORN MANIFOLD

The Characteristics of This Manifold Were Similar to Those of the Inverted Ramshorn Type Shown in Fig. 17. The Spiral Flow of Mixtures Was Almost Identical with a Resulting Very Bad Stratification

distribution. It was seldom known to what extent the formation of puddles controlled the distribution. In a few cases, however, where glass manifolds and transparent sections were employed, some judgment could be formed as to the parts played by stratification and by puddles. In other cases, when special devices, such as equalization rings, were employed, conclusions could be drawn based upon the knowledge that these devices in every case both controlled stratification to some degree and varied the size of the puddles. The artificial creation of puddles, however, is of doubtful value, since the amount of heat available on the walls of the manifold that tends to vaporize the puddles would naturally change their size. As a result the distribution could be very radically affected as the temperature of the engine changes.

One of the most annoying problems encountered in the flow of air through manifolds is the changeability of the type of air-flow. Observation of mixture-flow in transparent manifolds indicates that in the commercial types of device with standard carbureters the air-flow is constantly changing, even at a given engine-speed and a given throttle-setting. This condition is brought about by the fact that the air-flow is very turbulent. The turbulency is set up by uneven surfaces, sharp corners, throttle position, throttle shape, tortuous bends and other unfavorable conditions for smooth air-flow. It is well known in airplane practice that whenever turbulent air-flow exists uncertain performance will inevitably result. Observation of the photographs shown in Fig. 9 will give some idea as to the peculiar manner in which air acts when it is forced to travel through channels of peculiar shape. It is difficult to analyze exactly why the air flows past the throttle in the manner shown. It is the result, of course, of a set of forces that cause it to go in the easiest possible path. Air is a very light-weight fluid and, when subjected to the high pressures encountered in a manifold, naturally reacts in a peculiar manner. Very slight changes of throttle-setting sometimes change the direction of air-flow so completely that the liquid distribution is entirely upset. Even without any apparent mechanical changes, this unstable air-flow has been observed to change suddenly and take a new course, entirely upsetting the old distribution balance.

TESTS ON VARIOUS MANIFOLDS

Many manifolds have been measured on the cold-test machine, both standard and experimental. Some having glass sections, or made wholly of glass, have made possible the observations of mixture-flow that led to the analysis of the behavior of wet mixtures in the foregoing discussion.

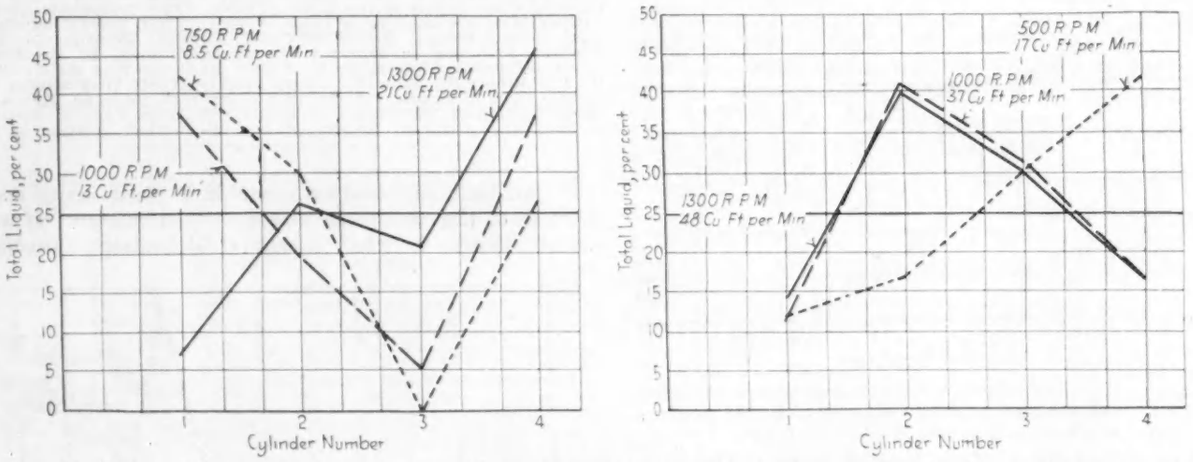

FIG. 20—LIQUID DISTRIBUTION TESTS OF THE GLASS RAMSHORN MANIFOLD SHOWN IN FIG. 19 WHEN EQUIPPED WITH DISTRIBUTING RINGS

These Tests Were Run at Full Throttle (at the Left) and Part Throttle (at the Right) and Different Engine Speeds and Flow Rates as Indicated

Tests on the cast-iron manifold shown in Fig. 10 appear in Figs. 11 and 12. It will be noted that these tests were made on two different manifolds. The results obtained were entirely different in the two cases, though the manifolds were made from the same pattern. This result is not surprising since it was possible to obtain several sets of performance curves from the same mani-

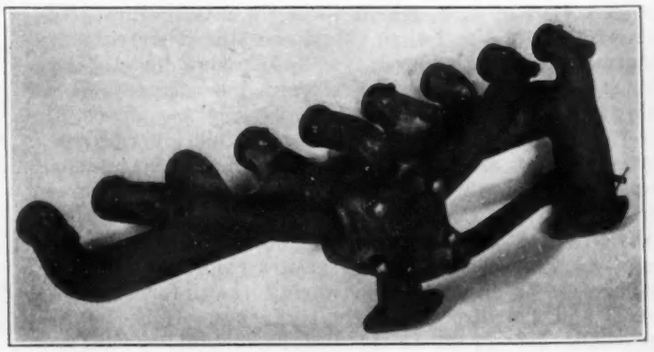

FIG. 21—A SIX-CYLINDER MANIFOLD THAT WAS TESTED

The Cold Distribution Obtained with This Manifold Was Very Erratic

fold, on account of the erratic behavior of the mixture-flow. It must be noted, however, that this manifold was of the hot-spot type and when hot really gave very good distribution. The hot-spot, which was located on the riser, provided sufficient heat to vaporize a large part of the fuel before any distribution occurred. To prove that good distribution under actual operating conditions should be obtained from this device, a series of exhaust-gas analyses was run. The results of these tests will be found in Fig. 13.

A four-cylinder square transparent manifold, which is shown in Fig. 14, was also tested. This manifold was made of celluloid and allowed complete observation of mixture-flow. Flow tests of the manifold did not indicate that the perfomance was much improved over that of the standard types, as will be noted in Fig. 15. The use of distributing rings in the end of each leg resulted in a change in the distribution at the higher rates of flow, as will be noted from Fig. 16. Other tests were made at a later date with this same combination, but the results were much more erratic in every case.

An inverted ramshorn type of manifold that was made largely of glass as shown in Fig. 17 permitted a detailed observation of the mixture-flow to be made. The carbureter flange fitting was attached by a piece of hose. This permitted rotation of the flange, which in turn allowed experiments to be made with the throttle positions in different rotational planes. The outstanding characteristic of this manifold was the peculiar manner in which the fluid streamers spiraled their way around the bends. The character of air-flow was such that it caused these streamers to change suddenly from one path on another without any apparent reason. These changes would occur without the mechanical shifting of any adjustments. This symptom was but another piece of evidence tending to indicate that with turbulent air-flow under comparatively high pressures almost any result might be expected. The curve sheet, reproduced in Fig. 18, shows very poor distribution.

The transparent manifold shown in Fig. 19 had characteristics similar to those of the inverted-ramshorn type. The spiral flow of mixtures was almost identical and as a result the stratification was very bad. The results of tests in which rings in the end of the legs were used are presented in Fig. 20.

The six-cylinder manifold illustrated in Fig. 21 was tested with the results shown in Fig. 22. The cold distribution was very erratic. Other tests with different firing-orders gave results that were different but equally bad.

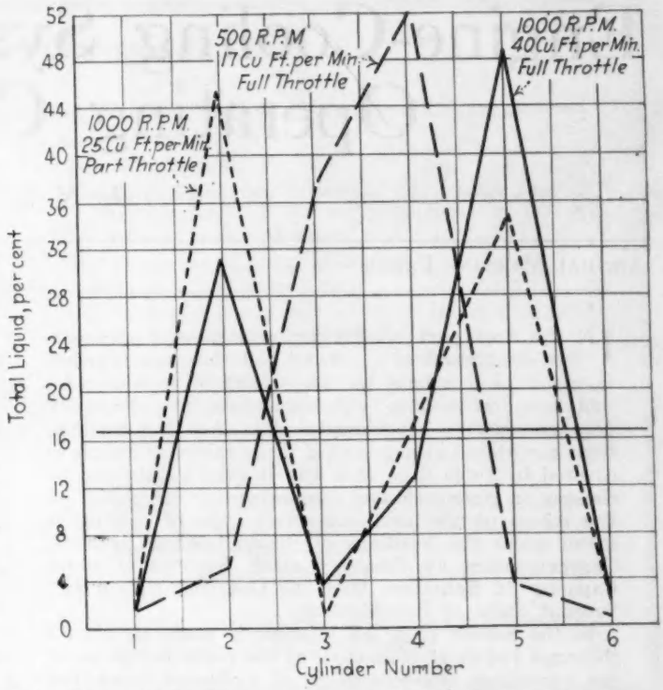

FIG. 22—LIQUID-DISTRIBUTION TESTS OF A SIX-CYLINDER MANIFOLD

These Results, which Were Obtained with a Firing Order of 1-2-3-6-5-4, Showed a Very Erratic Cold Distribution. The Results Obtained with Other Firing Orders Were Different and Equally Bad

CONDITIONS GOVERNING DISTRIBUTION

(1) Because of the low volatility of commercial fuels, heat must be applied if distribution in the gaseous state is to be attained

(2) If the fuel is not vaporized by hot-spots or other preheating devices, about one-half the fuel at 70 deg. fahr. must be distributed as liquid. At low temperatures, nearly all the fuel reaches the cylinder in a liquid state during the warming-up periods

(3) If sufficient heat is applied to dry the mixture, the resulting mixture-temperatures will be so high that the engine will be sensitive to detonation. If the compression is reduced to eliminate detonation, the power and the economy are also reduced

(4) All the commercial manifolds tested cold exhibited practically no inherent ability to distribute liquid

(5) Three main factors control the flow of air and liquid fuel in a manifold:

(*a*) The stratification of liquid with respect to the air

(*b*) Puddles of liquid that are formed in the manifold in dead-air pockets

(*c*) The effect of the firing order

(6) Stratification results from the fact that liquid fuel, which is many times heavier than air, is carried in the air stream in drops of varying size. Whenever the air stream makes a turn, some of the drops of liquid continue in the same direction as formerly. Stratification starts at the first turn, usually at the throttle, and becomes worse at each bend

(7) Puddles that form as a result of stratification and from other causes constitute a source of supply for the first cylinder demanding a charge, after that manifold branch has remained inactive during the functioning of another branch

(3) If sufficient heat is applied to dry the mixture, the controlled more readily if air-flow could be attained without turbulency. Since the forces involved are large and air is a very light-weight mobile fluid, freak flow results around every sharp bend and every protruding corner. The conventional throttle is *one* of the main causes of turbulent air-flow. Air-flow of this character is constantly changing its path even though the mechanical adjustments remain unaltered

Engine-Cooling Systems and Radiator Operating Characteristics

By N. S. Diamant[1]

Annual Meeting Paper *Illustrated with* Charts and Drawings

In the first part of the paper, a general quantitative comparison of air, water and oil-cooled cylinders is given as it relates to the subject of heat-transfer and temperature-drop. Unfortunately, the discussion does not include experimental data, but the assumptions are stated clearly and a large range of values is covered in Table 2 so that any desired values can be chosen. A thorough and comprehensive discussion of the steam or the radio-condenser type of cooling is given under the headings of Steam Cooling Systems, Characteristics of Steam Cooling Systems, Cooling Capacity of Radiators Used To Condense Steam and Present State of Development.

In the second part, an attempt is made to give a thorough but brief discussion of the performance or of the operating characteristics of radiators from the point of view of the car, truck or tractor designer. The cooling of aircraft engines is not considered. A great amount of original material is contained in this second part which should prove not only of direct value and use, but also of indirect value by interesting others in the solution of cooling problems. A summary is given at the end from which some of the salient points can be obtained without making a detailed study of the paper.

THE cylinder-cooling of practically all engines used at present in the various branches of the automotive industry, with the exception of motorcycle engines and the like, is accomplished by water-jacketing the cylinders. Air-cooled as well as oil-jacketed cylinders are being used commercially and successfully, but, so far, they have proved rather weak competitors of water-jacketed cylinders.

I am convinced that an open, broad-minded cooperation between the advocates of the various types and, above all, a systematic investigation of the fundamentals of the various cooling systems, will help all concerned to a better understanding of the principles involved and naturally will lead to refinements if not to radical improvements in passenger-car, truck and tractor performance, particularly in winter.

Heat-Flow and Temperature Distribution in Cylinders

Accounts of the interesting work done on air-cooled cylinders, particularly as it relates to aircraft engines, have appeared in The Journal and elsewhere. Reference may be made to Aircraft Engine Practice as Applied to Air-Cooled Passenger-Car Engines,[2] by S. D. Heron. No attempt will be made in this paper to review that work. However, it is considered advisable to direct attention briefly to cylinder-cooling from the point of view of heat-transfer and distribution of temperature at the cylinder-head and around the cylinder-walls, without particular reference to cylinder design. Thorough and systematic

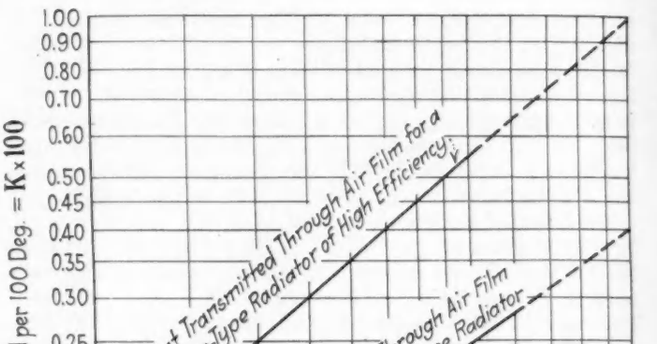

Fig. 1—Heat-Transmission Curves for Air Films at Various Velocities

The Ordinates Give 100 *K* or 100 Times the British Thermal Units Transmitted per Minute per Square Inch of Surface per Fahrenheit Degree Temperature-Difference between the Metal of the Radiator and the Air. The Upper Curve Is the Heat Transmitted through an Air Film for a High-Efficiency Ribbon-Type Radiator, while the Lower Gives the Same Information for an Ordinary Ribbon-Type Radiator. These Values Are Probably Somewhat High for Air-Cooled Cylinders

information is not available about the temperature distribution in the cylinders and in the piston of water-jacketed, oil-jacketed and air-cooled engines under various conditions of operation. Further, we do not know at present to what extent the temperature distribution can vary without affecting materially the performance of the engine. In general we know that the design of water-cooled engines, along conventional lines, is an easier and less doubtful problem than the design of air or oil-cooled engines.

To appreciate the importance of the foregoing, let us take a water-cooled and an air-cooled engine and suppose we succeed in securing, somehow, the same temperature distribution in each case; it would seem that their performance should be practically identical; it should not make any difference to the engines how the temperature distribution is obtained so long as it is practically the same for both. Referring to the lower curve in Fig. 1, we find that if the air velocity is 30 m.p.h. or 44 ft. per sec. past a surface on the cylinder 1 sq. in. in area, the heat-transfer will amount to 0.18 B.t.u. per min. per 100-deg. fahr. difference between the metal and the air. If the air-speed is 60 m.p.h. or 88 ft. per sec., the heat abstracted by the air will be 0.30 B.t.u. per min. per 100 deg. fahr. If water be used instead of air, ac-

[1] A.S.A.E.—Consulting engineer, Jamestown Car Parts Mfg. Co., Jamestown, N. Y.

[2] See The Journal, January, 1923, p. 31.

KEY TO SYMBOLS

The symbols given below relate to the charts reproduced as well as to the text of the paper, and are grouped in this manner for ready reference by the reader:

A = Frontal area in square feet

$C = (v_a/v_f)$ = airflow constant

$\triangle P$ = Pressure-Drop across the radiator core in inches of water

$\triangle t_d$ = Temperature-Drop producing heat-flow

$\triangle t_r$ = Temperature-Rise of the air going through the radiator core

δ = Density of air under a specified set of conditions of temperature, pressure and humidity

H_d = Heat dissipation of the radiator core

$H_f = (k/T)\ A \triangle t_d$ = Heat-Flow = $KA \triangle t_d$

h_p = Pressure-head in inches of water

h_{vf} = Velocity-Head corresponding to a car speed v_f

K = Coefficient of heat-transmission in British thermal units per minute per square inch per degree Fahrenheit

k = Thermal-Conductivity in British thermal units per minute per square inch of a surface 1 in. thick per degree Fahrenheit

$m = v_a A \delta$ = Mass-Flow of air through the radiator core

n = An exponent

R = Head-Resistance in pounds per square foot of frontal area of the radiator core; = 5.2 × head in inches of water

T = Thickness of metal in inches

t = Mean air-temperature

t_1 = Temperature of the air that enters the radiator, in degrees Fahrenheit

t_2 = Temperature of the air that leaves the radiator, in degrees Fahrenheit

Θ = Mean water-temperature

Θ_1 = Top tank-temperature in degrees Fahrenheit, or the temperature of the water as it leaves the engine

Θ_2 = Bottom tank-temperature in degrees Fahrenheit, or the temperature of the water as it enters the engine

v_a = Actual velocity of the air in front of the radiator

v_f = Flying speed, or the free air-speed corresponding to the car or truck speed

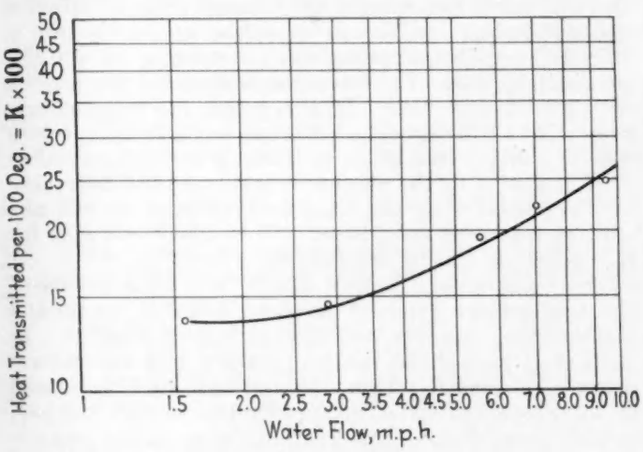

FIG. 2—CURVE OF HEAT TRANSMISSION FOR WATER FILM
The Data on Which This Curve Is Based were Obtained from a Cold-Rolled Steel Tube Having an Outside Diameter of 1.253 In. and an Inside Diameter of 0.985 In.

cording to Fig. 2 the amount of heat transferred from the same 1 sq. in. of surface will be 15 B.t.u. per min. per 100-deg. fahr. difference between the metal and the water, for a water velocity of 3 m.p.h. or 4.4 ft. per sec. or 90 lb. per min. through a pipe of 1-in. inside-diameter. In other words, at one-tenth the velocity, water abstracts 90 times as much heat as air for the same temperature-difference. On the other hand, oil at 3 m.p.h. or 4.4 ft. per sec. abstracts 1.6 B.t.u. per min. per 100 deg fahr., or about 10 times as much heat as air, as is brought out in Fig. 3.

The upper curve in Fig. 1 shows an air-film conductance that I doubt has ever been approached in any air-cooled cylinder design. In fact, in all probability, the lower curve gives values that are too high so far as present practice is concerned; however, the upper curve is interesting, as it shows what can be accomplished when one is not handicapped too much with considerations of engine design. The flow of heat across the metal of a cylinder-wall or a cylinder-head if fairly uniform in thickness and shape can be calculated with considerable accuracy as compared to the heat-flow from metal to air, oil or water. For example, we have according to Table 1 a resistance of 9 for cast iron, referred to copper, or a conductance of about 3.8 B.t.u. per min. per 100 deg. fahr. per sq. in. of wall 1 in. thick; or 15.2 B.t.u. per min. per 100 deg. fahr. per sq. in. for a wall ¼ in. thick.

Summarizing the foregoing, we can state that the amount of heat abstracted from the cylinders of an engine will vary considerably according to the cooling medium used, whether it be water, air or oil. It will depend on the mass-flow of the cooling medium; further, it will depend on the extent to which the flow is turbulent. It will depend also on the size and the shape of the jacket or the cell through which the cooling fluid flows; that is, it will depend on the ratio of the cooling surface

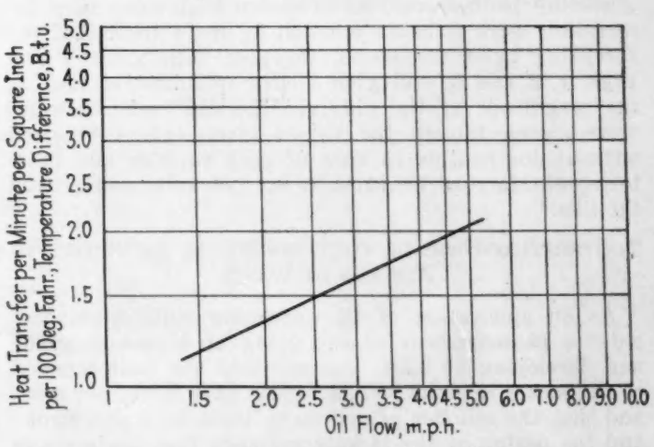

FIG. 3—CURVE OF THE COEFFICIENT OF HEAT TRANSFER BETWEEN METAL AND AN OIL STREAM
The Viscosity of the Oil Used Was 50 Saybolt Sec. This Curve Should Be Compared with Those for Air in Fig. 1. It Should Be Noted in This Connection That for the Same Flow-Rate the Oil Abstracts 10 Times as Much Heat as Air

TABLE 1—THERMAL CONDUCTIVITY OF VARIOUS SUBSTANCES

Material	Temperature, Deg. Fahr.	Conductivity in British Thermal Units per Minute per Square Inch of Surface per Inch of Thickness per 100 Deg. Fahr.	Comparative Thermal Resistance
Air at Rest	32	0.00174	19400
Air at Rest	212	0.00191	.....
Air in Motion, See Fig. 1	...	.....	.....
Aluminum	64	16.20	2.10
Aluminum	212	16.60	2.05
Cast Iron	129	3.85	8.83
Cast Iron	216	3.74	9.10
Castor Oil at Rest	...	0.1435	2370
Copper	64	30.90	1.10
Copper	212	30.60	1.11
1-Per Cent Carbon Steel	64	3.64	9.32
Paraffin	63	0.0119	2870
Petroleum Oil at Rest	55	0.1190	2860
Silver	64	34.00	1.00
Silver	212	33.30	1.02
Water at Rest	63	0.0505	672
Water at Rest	77	0.0460	740
Water in Motion, (See Fig. 2)	...	.....	....

to the sectional area through which the cooling fluid flows; this ratio is called the hydraulic radius.

The problem of heat-transfer is extremely complicated and, old as it is, our knowledge of it is not very satisfactory. Its importance in all branches of engineering is, however, so extensive that some very interesting work is being done on it, and I trust that the foregoing brief discussion, together with Table 1 and Figs. 1, 2 and 3, will give a clear quantitative idea of the magnitude of the different thermal resistances involved, even though the values given cannot be used without due caution in view of such variable and indeterminate factors as turbulence, hydraulic radius and the like.

TEMPERATURE-DROP IN CYLINDER-METAL, IN SCALE, IN AIR AND IN WATER

As an application of the foregoing statements, consider a passenger-car engine going up a certain grade and developing 30 b.hp. Assume that the heat rejected to the jacket is 30 hp., which equals 1270 B.t.u. per min., and that the number of cylinders, their bore and stroke and the design of the jackets are such that the average heat rejected to the water is 1270 B.t.u. per min. divided by 254 sq. in., or 5 B.t.u. per min. per sq. in. of wetted surface of the cylinder-jacket. From this information we can determine the temperature-drop from the metal to the water and that through the cylinder-wall metal, if we know or assume the conductivity k of the cylinder-metal and K for the water-film.

Then, H_f, the heat-flow per square inch of cylinder-surface, is

$$H_f = K \cdot \triangle t_d = (k/T) \triangle t_d$$

Assuming $K = 0.100$ for water and $k = 0.037$ for cast iron, we have: $H_f = 5 = 0.1 \times 1 \times \triangle t_d$ for the water-film; and $H_f = 5 = (0.037 \times 1 \times \triangle t_d)/0.20$ for the metal. Hence $\triangle t_d$ is 50 deg. for the water-film and 2.7 for the cast iron. Assuming the temperature of the water in the jacket to be 200.0 deg. fahr., the temperature of the cast iron will be 250.0 deg. on the water side and 252.7 deg. on the combustion side. Thus, it is clear that the temperature gradient in the cylinder-metal is low; of course, a very large temperature-rise occurs in the oil-film on the combustion side.

If the engine has a thermosiphon circulation the conductance of the water-film will be less than the value assumed in the example just given. Assuming K as 0.015 we find a temperature-drop across the water-film of 333 deg. fahr. Hence the temperature of the cast-iron jacket will be 533.0 deg. on the water-side of the jacket and 535.7 deg. on the combustion side, assuming, as before, the water temperature to be 200.0 deg.

Next, suppose that this engine is air-cooled and has about 28 sq. in. of effective cooling surface per b.hp., or $30 \times 28 = 840$ sq. in. in all. Thus, the heat in British thermal units per minute per square inch of effective cylinder-cooling surface to be taken up by the air is $1270/840 = 1.5$ approximately. Assuming $K = 0.002$, we shall find that the temperature-drop in the air-film will be 750 deg. fahr. If $K = 0.003$, the temperature-drop will be 500 deg. fahr. Values of $\triangle t_d$ for $K = 0.0010$ and $K = 0.0015$ are given in Table 2 for various values of H_f. Assuming the air temperature to be 80 deg. fahr., the temperature of the air-cooled cylinder on the air-side, at the point considered, will be about 830 deg. for $K = 0.002$; it will be 580 deg. for $K = 0.003$.

These examples, I believe, give a very clear picture of the temperature gradient in water-jacketed, pump and thermosiphon engines and also air-cooled engines. In Table 2, I have given the temperature-drop for various values of H_f and K. Thus, the assumptions I have made in the above examples can be changed to suit the particular case under consideration, when more experimental data are available on the values of H_f and K which obtain in commercial engines.

The question naturally will arise as to the effect of scale formed in the jackets. A coating of this character will increase the resistance to heat-flow and will reduce the heat transmitted for a given temperature-drop, $\triangle t_d$; or, it will increase $\triangle t_d$ for a given amount of heat-flow. The main difficulty here is to determine the value of K. In view of lack of data on the subject in the last four columns of Table 2, I have given the temperature-drops for $K = 0.250$, $K = 0.050$, $K = 0.005$ and $K = 0.010$. Further, for the sake of completeness, I have given the temperature-drops for different amounts of heat-flow H_f, since my purpose is to discuss the fundamentals of the different cooling systems without favoring or seeming to favor any of them.

STEAM-COOLING SYSTEMS

Water-cooling systems will be discussed further when we take up the fundamentals of the performance of radiators, in the second part of the paper. Let us now turn our attention to the so-called radio-condenser or steam or evaporative system of cooling. In this sys-

tem the cylinders are water-jacketed as usual but the water, instead of being cooled in the radiator, is allowed to boil first and the steam thus evolved is condensed in the radiator and returned to the system.

One of old steam engine-cooling systems is shown in Fig. 4. Reference is made to another system, that of Gillet-Forest[3]; and to others discussed in recent issues of the technical press.

Characteristics of the Steam-Cooling System

The primary advantage of the system is the fact that the water coming from the engine is always at the same temperature; it is 212 deg. fahr. for water at atmospheric pressure or less than 212 deg. fahr. if alcohol be mixed with the water, or the pressure be reduced below that of the atmosphere. It is above 212 deg. fahr. in systems maintained at pressures higher than atmospheric. The temperature of the water returned to the engine is about 10 to 15 or even 20 deg. fahr. lower, depending upon the amount of condensate and its temperature. Of course, if desired, the water can be returned to the top of the engine jacket, instead of to the bottom, in which case the temperature difference of the water at the top and at the bottom of the engine jacket will be only a few degrees. Summarizing the main characteristics of the system we have:

(1) The temperature of the water in the jackets of the engine is constant, irrespective of the load, the speed or the weather conditions

(2) Normal operating temperature of the cooling liquid is attained readily, and the time taken to reach this temperature is affected comparatively little by outside weather conditions

(3) The engine cools down very slowly, compared to the present water-cooled system; in the case of tractors, this has the added advantage that it facilitates starting on kerosene after a short stop

(4) If water be excluded entirely from the radiator, the nuisance of leaky cores is reduced to the minimum

(5) With a well-designed system, the amount of water lost should be small enough so that the system can be filled and operated with distilled water, thus eliminating or, at least, greatly reducing the nuisance of alkaline and dirty water

(6) The heat-dissipating capacity of the radiator, for a given set of conditions, is increased in direct proportion to the increase in the temperature difference between hot water and air, and between steam and air

(7) Freezing troubles are reduced, but are not eliminated. However, the great expense of replenishing regularly the alcohol evaporating from the ordinary cooling system is eliminated; also, the common danger in thermosiphon jobs of freezing the radiator when an unexpected cold wave sets in, is overcome

(8) Though actual data are lacking, no doubt the constant and uniform temperature of the water in the cylinder-jackets would reduce greatly troubles due to the unequal expansion of the cylinders and the pistons, crankcase dilution and the like

(9) Finally, the terms "overcooling" and "undercooling" lose their meaning. Overcooling is impossible, and undercooling would result merely in a loss of steam through the vent or the safety valve

[3] See *Horseless Age*, March 25, 1903, p. 408.

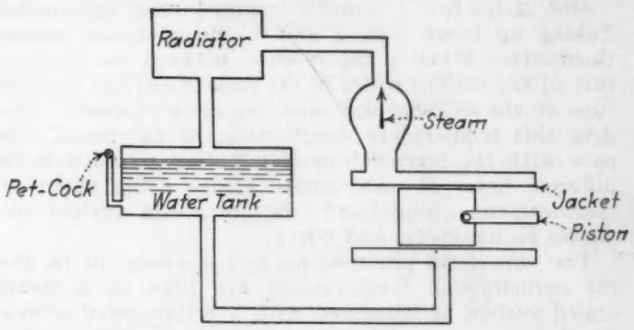

Fig. 4—Radio-Condenser or Steam System of Cooling Used by Benz in 1890

The Principal Advantage of This System Is That the Water Coming from the Engine Is Always at the Same Temperature, 212 Deg. Fahr. at Atmospheric Pressure, Less if the Pressure Is Reduced or Alcohol Be Mixed with the Water and More if the Pressure Be Higher than That of the Atmosphere. The Temperature of the Water Returned to the Engine Is from 10 to 20 Deg. Lower, Depending upon the Amount of Condensate and Its Temperature

Table 2—Temperature-Drops Due to Various Amounts of Heat-Flow per Square Inch of Effective Cylinder-Cooling Surface for Different Values of Conductances[4]

Heat-Flow from Cylinder to Cooling Medium, British Thermal Units per Minute per Square Inch of Effective Cylinder-Cooling Surface	Temperature-Drop in Deg. Fahr., Δt_d								
	In Water-Film $K=0.10$	In Water-Film $K=0.15$	In Cast Iron 0.20 In. Thick $K=0.037$	In Air-Film $K=0.0010$	In Air-Film $K=0.0015$	In Scale $K=0.25$	In Scale $K=0.05$	In Scale $K=0.005$	In Scale or Oil $K=0.010$
0.5	5	3.3	0.3	500	330	2	10	100	50
1.0	10	6.7	0.5	1,000	670	4	20	200	100
2.0	20	13.3	1.0	2,000	1,330	8	40	400	200
3.0	30	20.0	1.6	.....	2,000	12	60	600	300
4.0	40	26.7	2.1	.....	.....	16	80	800	400
5.0	50	33.3	2.7	.....	.....	20	100	1,000	500
7.0	70	46.7	3.8	.....	.....	28	140	1,400	700
10.0	100	67.0	5.3	.....	.....	40	200	.....	1,000
15.0	150	100.0	8.0	.....	.....	60	300	.....	.....
20.0	200	133.0	10.7	.....	.....	80	400	.....	.....
25.0	250	167.0	13.3	.....	.....	100	500	.....	.....

[4] H_f = Heat-Flow per square inch of surface = $(k/T)\ \Delta\ t_d$ for cast iron.
$H_f = (K\ \Delta\ t_d)$ for water-film or air-film, etc.

Only items Nos. 1, 8 and 6 require further explanation. Taking up items Nos. 1 and 8, the questions suggest themselves: What is the relation between the temperature of the boiling water in the jackets and the temperature of the cylinder-wall and the cylinder-head? How does this temperature distribution, in the metal, compare with the temperature distribution obtained in the different types of water-cooled engine using pump and thermosiphon circulation? Is the steam system conducive to hot-spots, and why?

The superficial engineering notion seems to be that the cylinder-wall temperatures are high in a steam-cooled system as compared with a water-cooled system. Further, it appears that the popular view is inclined to assume that the cylinder-wall temperatures in the ordinary water-cooled job are not much above the temperature of the water coming from the cylinders; this view is based on or corroborated by the fact that these jobs do not give any trouble, which is true.

Although reliable and extensive data are lacking, a great amount of information can be secured from the foregoing discussion and from Table 2. Referring to the example given before and assuming a heat-flow of 5 B.t.u. per min. per sq. in. of cylinder-surface, the temperature-drop through a coating of scale will be 100, 500 or 1000 deg. fahr., according to whether the value of K is 0.050, 0.010 or 0.005. Thus, the temperatures of the cylinder-metal of ordinary water-cooled engines may or may not be as low as it is usually assumed. Of course, if we have a steam or an air-pocket in the cylinder-jacket, the cylinder-temperature at that point may attain very high values indeed, since K for air at rest or steam at rest is extremely low; the thermal resistance of either air at rest or of steam at 212 deg. fahr. and at rest is nearly 19,000 times as high as that of copper 1 in. thick. Further, judging from the data available on steam boilers and other heat-exchange apparatus, hot-spots, steam or air-pockets are not necessarily inherent in a radio-condenser system of cooling but apparently are due to defective jacket-design.

Some of the quantitative results already given may seem at first unexpected or improbable, and some of them may not be wholly correct; however, I trust that they show clearly the importance of doing some systematic work along the lines indicated. The development of air-cooled or steam-cooled engines is very useful, but a systematic investigation of the fundamentals will yield results of more far-reaching usefulness than any rule-of-thumb development of cylinders or engines.

Cooling-Capacity of Radiators Used To Condense Steam

Returning to item No. 6, we can state as a known fact that the cooling-capacity of a given radiator, under a given set of conditions, will increase directly as the increase in the temperature difference between the mean water and air temperatures, and between the steam and air temperatures. For example, suppose that a given engine rejects to the jacket 1500 B.t.u. per min. at a given load and speed. These 1500 B.t.u. per min., which are equal to 35.5 hp., will heat the water in the jacket to let us say 190 deg. fahr.; suppose that the water returns to the engine at 170 deg. fahr. when the temperature of the air entering the radiator is 80 deg. fahr., so that 180 — 80, or 100, equals the difference between the mean water-temperature and the entering air-temperature. If this engine be equipped with a radio-condenser type of cooling, the same 1500 B.t.u. per min. will go to heating the water as before, and when steam is given off at the free surface of the water, it will enter the radiator, be condensed and returned to the system. The radiator now is not any more efficient than it was before; it is the same radiator, but its capacity is increased in the ratio of $(212 - 80)/(180 - 80) = 132/100 = 132$ per cent.

Thus, a radiator (100/132) 100, or 76 per cent as large as the first, will be sufficient to maintain the jacket top-temperature at 212 deg. fahr., just as the first radiator maintained the water temperature at 190 deg. fahr. In all this I have assumed that the water circulation through the radiator is large enough not to affect the heat-transfer efficiency of the radiator. If the water-flow through the radiator is more than 3 gal. per min. per in. of core depth per ft. of width, the heat-transfer coefficient of the core per unit temperature-difference between the metal and the air will be about the same as when steam is used. However, if the water-flow is reduced, the heat-transfer is reduced slowly at first, and very rapidly at lower water-velocities; thus, for a thermosiphon system, the gain is very much larger in changing to steam cooling, as will be discussed under a subsequent heading: Effect of Water-Flow on Cooling-Capacity.

In this connection it is well to call attention to the fact that the temperature of the condensate gives little indication as to the cooling-capacity of a radiator. Suppose that the cooling-capacity of radiator A is 110 per cent of the cooling-capacity of radiator B, and that all other characteristics, such as those of water-flow and the like, are the same for both radiators. If we try these on a chassis we shall find that, under a given set of conditions, if the bottom tank-temperature of radiator B is 180 deg. fahr, that of radiator A will be approximately $(100/110)\ 180 = 164$ deg. fahr.

Next, suppose that we use these same radiators on a steam-cooled chassis and assume that, under a given set of conditions, about 2 lb. of steam are evolved per minute. Suppose that radiator B is able to condense these 2 lb. of steam into water at 212 deg. fahr. What will radiator A do? We find that (100/110) or 0.91 of its cooling-capacity will be used to condense the 2 lb. of steam into water at 212 deg. fahr.; the remainder, which, let us say, is able to dissipate 200 B.t.u. per min., will be used in reducing the temperature of the condensate from 212 to about 112 deg. fahr., since 2 lb. of water when cooled down from 212 to 112 or 100 deg. fahr. will absorb 200 B.t.u. Thus, the water returned to the engine is at 212 deg. fahr. in case of one radiator and 112 deg. fahr. in case of the other radiator 110 per cent as large.

Present State of Development

A feeling seems to exist that the steam or radio-condenser type of cooling is involved at present in patent litigation and that it will attract the attention of engineers and manufacturers when the situation clears up[5]. Anyone who cares to take the trouble to look up the files of the *Official Gazette of the United States Patent Office* will find that a number of patents have been issued in the last 10 years to patentees living anywhere from the Pacific to the Atlantic coast. Further, it is reasonable to expect that a number of applications will be made in the next few years. It is hoped that each and every patentee will get a fair and square deal and a just return for what he contributes to the subject; however, it is also hoped that in the meantime some constructive

[5] See THE JOURNAL, February, 1923, p. 117.

work will be done and that the present systems of cooling will be perfected or new ones developed, since the question of cooling is intimately connected with the performance of the engine, its gasoline consumption and the like.

In the first part of the paper I considered the different cooling systems. In this second part it is proposed to take up the fundamental operating characteristics of commercial radiators as used on water-cooled engines having pump or thermosiphon circulation.

Effect of Airflow on Radiator Performance

The variation of cooling capacity with airflow can be represented by H_d = a constant $\times m^n$, where n varies between 0.5 and 1.0 and m is the airflow in pounds per minute per square foot of frontal area or in some equivalent units. It is most convenient to express m in terms of velocity as follows: Let the airflow 6 to 8 in. in front of the core be 30 m.p.h. or 2640 ft. per min.; and let the section of the wind tunnel be 17 x 17 in. or about 2 sq. ft., the same as the size of the core. Assuming the density of the air as 0.075 lb. per cu. ft., $m = 2640 \times 2 \times 0.075 = 396$ lb. per min. through the 2-ft. section; or 198 lb. per min. per sq. ft. of frontal area; or 3.3 lb. per sec. per sq. ft. Thus, instead of plotting heat dissipation against pounds per minute per square foot, we can plot it against actual velocity v_a in front of the core. It is understood that the air velocity through the core will be higher, depending upon the percentage of free area of the core. This is the most convenient way to express airflow, and Fig. 5 gives the heat dissipation and the air-temperature rise of a good average core in terms of v_a.

One method of obtaining the necessary data for Fig. 5 is to take a 17 x 17-in. core, place it in a tunnel of the same section and measure its heat dissipation at various velocities, as read by Pitot tubes as indicated in Fig. 6. Pitot tubes, or grids as used by the Bureau of Standards, give satisfactory results when placed from 6 to 8 in. in front of the radiator core. The heat dissipation can be calculated from the heat input; or from the temperature rise of the air and its mass-flow; or from the temperature-drop of the water and its mass-flow.

Tests such as have just been described are useful and necessary, but the question of importance to a passenger-car, truck or tractor designer or user is the amount of heat the same radiator will dissipate when mounted on the particular job in which he is interested. This brings us to a very important but much neglected subject, the amount of airflow through a radiator core.

[6] See National Advisory Committee for Aeronautics Report No. 63.

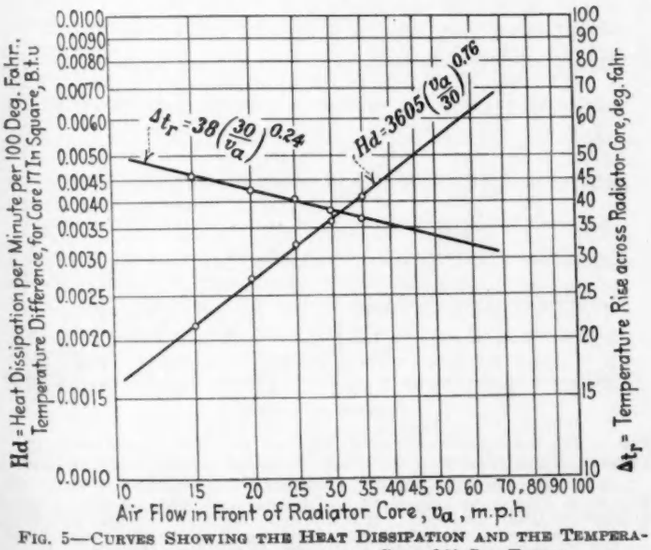

Fig. 5—Curves Showing the Heat Dissipation and the Temperature-Rise across a Radiator Core 2½ In. Thick

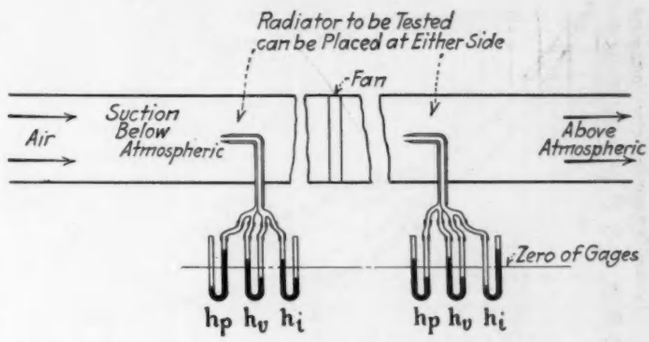

Fig. 6—Set-Up for Testing Radiator Cores at Various Air Velocities

In This Test the Heat Dissipation at Various Velocities Is Measured, the Velocity Readings Being Obtained by a Pitot Tube Connected in the Usual Way. The Drawing Illustrates the Fact That H_i, the Impact or Total Head, Is Equal to the Sum of H_p, the Pressure Head, and H_v, the Velocity Head

Airflow Due to Car Motion

First, let us consider the effect of free air-speed, irrespective of the fan. Suppose a car is traveling in still air at 50 m.p.h.; what will be the velocity of the air drawn through the radiator? A car speed of 50 m.p.h. represents a head of 1.21 in. of water and, if the pressure-drop through the core, as measured by an ordinary differential gage, is 0.91 in. of water, then the air velocity through the radiator will be 25 m.p.h., which corresponds to a head of 1.21 — 0.91 = 0.30 in. of water. In general, we can state this law as follows: the head, h_{vf}, produced by the motion of a vehicle traveling at a velocity v_f will set up an air velocity v_a in front of the radiator such that the head consumed in overcoming the pressure-drop in the core due to v_a, plus the head corresponding to v_a, will equal the head h_{vf}. In hydraulics, this is known as Bernouilli's principle; it merely states that the total head available equals the sum of the various velocity and friction heads. A second law states that the ratio of the useful velocity, v_a to v_f, is constant for nearly all values of v_f. Thus, in the example given above, the ratio was 25 to 50 = 0.5 and, therefore, at a car speed of 60 m.p.h. $v_a = 30$ m.p.h.; at a car speed of 15 m.p.h. $v_a = 7.5$ m.p.h., and so on. These two laws have been reduced to a mathematical form and are graphically represented by the lower curve in Fig. 7.

The experimental data upon which this curve is based are very meager and, to test it further, I have made use of the data published by the Bureau of Standards[6] in connection with its excellent work on aircraft radiators. If v_f is the flying speed of a radiator and this corresponds to a mass-flow of 10 lb. of air per min. per sq. ft. of frontal area, but the mass-flow through the radiator cores is 7 lb. per min. and corresponds to a velocity v_a, then the airflow constant C, for the unobstructed positions, is defined as v_a/v_f, and equals 0.7 in the example. This is similar to the definition given before, and it was found that C is nearly constant for different values of v_f, as stated above. From the data given in the report of the Bureau of Standards, I derived an equation which is shown in the upper curve of Fig. 7. Inspection of the curves shows an agreement between them of 5 to 10 per cent with the important difference that the upper curve refers to aerodynamic head-resistance, as measured

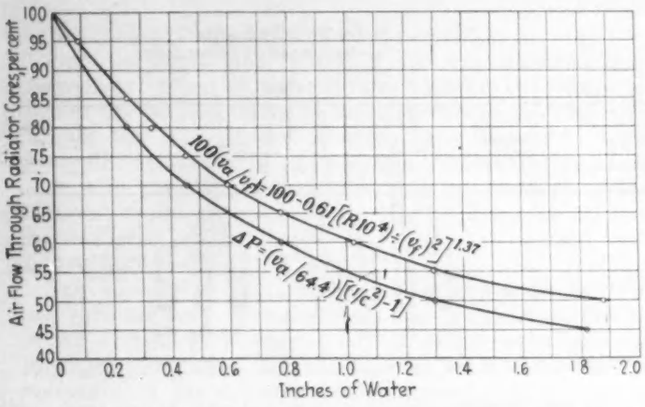

FIG. 7—CURVES SHOWING THE PERCENTAGE OF AIRFLOW THROUGH RADIATOR CORES HAVING DIFFERENT HEAD-RESISTANCES WHEN THE CORES ARE PLACED IN A STREAM OF AIR HAVING A UNIFORM FREE AIR-SPEED

The Upper Curve Is Based on the Aerodynamic Head Resistance in Inches of Water at an Actual Air Velocity of 30 M.P.H. or 198 Lb. per Min. per Sq. Ft. or 3.3 Lb. per Sec. per Sq. Ft. The Lower Curve Is Based on the Pressure-Drop in Inches of Water across the Radiator Core at an Actual Air Velocity of 30 M.P.H.

in a wind tunnel by a balance; this, for the sake of uniformity, I have expressed in inches of head of water instead of pounds per square foot, and also in terms of actual velocity in front of the core instead of terms of flying speed. The other curve is plotted against pressure-drop, $\triangle P$, across the radiator as determined in a tunnel having a section which is equal to that of the core.

AIRFLOW INDUCED BY THE FAN

In Fig. 8, the volume of air drawn by two 18-in. fans of the propeller and disc type is shown, when operated at 1060 and 1380 r.p.m., respectively, against different continuously maintained pressures. A glance at these curves shows that the amount of air drawn through a given core depends on the type of fan and its design and that it is possible for a fan to draw more air through a high-resistance core than through a low-resistance core. For example, if a core having a pressure-drop of 0.2-in. head of water at 2250 cu. ft. per min. of air is placed in front of the propeller fan revolving at 1380 r.p.m., it will pass 2250 cu. ft. per min. of air. If it is placed in front of the disc fan operating at the same speed, it will keep on passing more air until an equilibrium is established so that the pressure-drop across the core is equal to the static pressure developed by the fan at the same airflow. But the pressure-drop of cores varies, in general, as the 1.8 power of the velocity v_a; so, in this case $\triangle P$ at any airflow times the number of cubic feet per minute is

$$\triangle P = 0.2\ (x/2250)^{1.8}$$

From this equation we find that the same core, when placed in front of the disc fan operating at 1380 r.p.m. will pass 2650 cu. ft. per min. of air, or 18 per cent more air than when used with the propeller type at the same speed. The power consumed by the fans will be about 0.25 hp. for the propeller and 0.45 hp. for the disc type. In a similar way we find that a core having a pressure-drop of 0.5 at 1700 cu. ft. per min. or 0.83-in. head of water at 2250 cu. ft. per min. will pass the same amount of air when used with either of the fans. The power consumed will be 0.55 hp. for the disc and 0.45 hp. for the propeller fan. Finally, a core having a pressure-drop of 0.8-in. head of water at 1200 cu. ft. per min. will pass 1130 cu. ft. per min. and will develop a pressure of 0.73-in. head of water with a disc fan, though it will pass 1200 cu. ft. per min. of air with a propeller fan. The power consumption in this case will be about 0.65 and 0.55 hp., respectively.

It is clear from these examples that, in general, a low-pressure radiator will draw more air and show higher heat-dissipation when tested or used with a disc fan; a high-pressure core will draw more air and therefore show higher heat-dissipation when tested with a propeller-type fan. In Fig. 8 it is seen that the discharge curves intersect; pressures to the left of this point of intersection are to be considered as low and pressures to the right of it as high. Further, if the radiator pressure falls to the right of the point of intersection, it will remain to the right; as the point of intersection shifts with the fan speed; and if it is on the point of intersection it will remain on the point of intersection for practically all speeds of the fan. The reason for this is that the pressure developed by the fan varies as the square of the fan speed, while the amount of air handled varies directly as the fan speed, and the radiator pressure-drop varies nearly as the square of the airflow; or, to be exact, as the 1.8 power.

The importance and bearing of the above on the cooling of cars and particularly trucks and tractors requires little comment. Possibly, it serves to explain why some fin-and-tube cores are made with staggered tubes and also why the spacing and the arrangement of the tubes varies so much in different radiators. However, it must

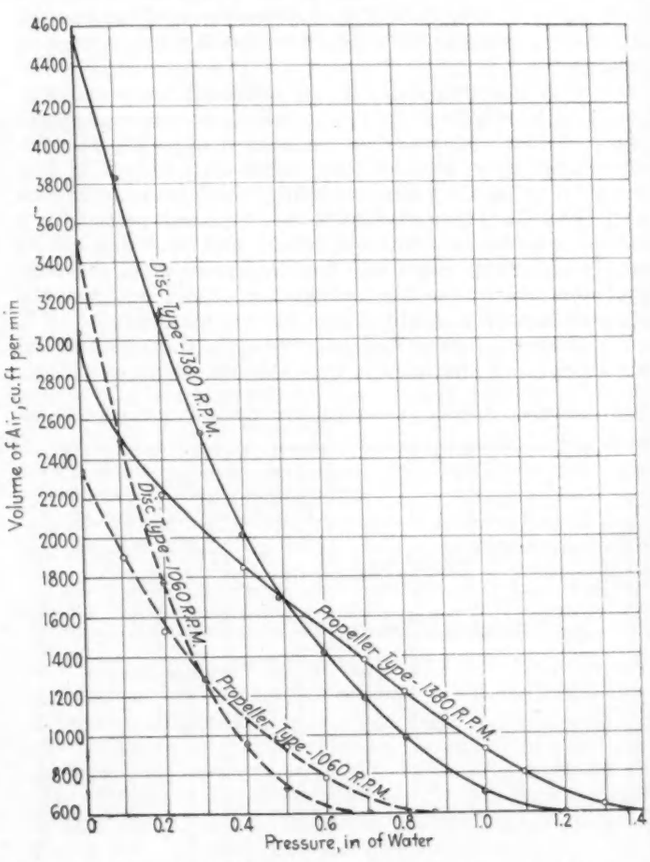

FIG. 8—CURVES SHOWING THE VOLUME OF AIR DISCHARGED BY PROPELLER AND DISC TYPE FANS AT DIFFERENT SPEEDS WHEN WORKING AGAINST VARIOUS CONSTANT PRESSURES

The Fans Which Measured 18 In. in Diameter Were Operated at Speeds of 1060 and 1380 R.P.M. The Amount of Air Drawn Through a Given Core Depends upon the Type of Fan and Its Design, It Being Possible for a Fan To Draw More Air through a High-Resistance Core than through a Low-Resistance Core

also be clear that a radiator will give good results only if used intelligently with the proper type of fan.

Resistance to Water-Flow

The impression is general that a radiator core, made up as it is of a series of small tortuous water courses, has extremely high resistance to water-flow. This, however, is not necessarily the case. In fact, I have found that even some of the worst offenders among commercial cores are equivalent to an orifice approximately from 0.8 to 1.0 in. in diameter. To clarify our ideas on this subject, let us consider the water-flow through orifices of various sizes under a head of 2 ft. The upper curve of Fig. 9 illustrates this graphically; for example, the water-flow through an orifice 1 in. in diameter is 150 lb. per min.

The lower curve of Fig. 9 gives the gravity water-flow through a core 17 x 17 in. in which the top tank

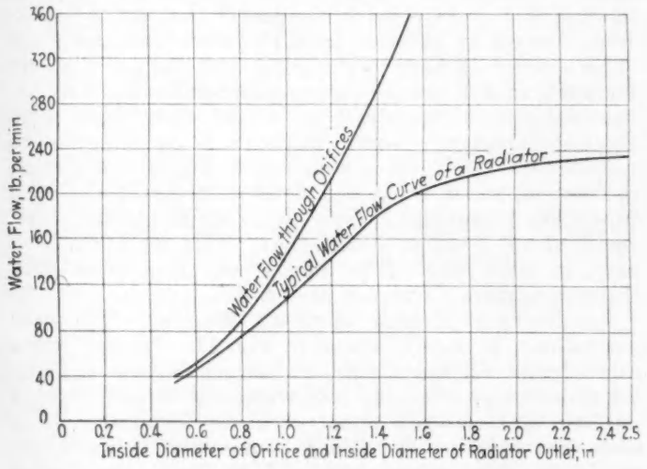
Water Flow, lb. per min
Water Flow through Orifices
Typical Water Flow Curve of a Radiator
Inside Diameter of Orifice and Inside Diameter of Radiator Outlet, in

Fig. 9—Curves of Resistance to Water Flow

The Upper Curve Shows the Water Flow through Orifices of Different Sizes under a Head of 2 Ft., the Coefficient of Discharge Being Taken as 0.65. The Lower Curve Is a Typical Water-Flow Curve for a Radiator Having Three Water Tubes per Inch of Core Width and Equipped With Outlets of Various Diameters. The Core in this Case Was 17 In. Square and the Head Was Approximately 22 In.

was maintained just about full and the head at the bottom tank-outlet was about 22 in. This core, when equipped with an outlet of 1-in. inside-diameter, passed 110 lb. of water per min. Thus, the resistance of the radiator in series with that of a 1-in. outlet reduced the water-flow of the latter from 150 to 110 lb. per min. It is clear from Fig. 9 that the resistance of the core shown begins to become the controlling resistance after the inside diameter of the outlet has been increased to 2.5 in., and any further increase in the outlet size will serve practically no good purpose.

Considering the water-circulating system as a unit, it is clear that the resistance of the core is such that cylinder-jackets, manifolds, bends, elbows and bottom tank-outlet sizes should all be designed properly if the total resistance of the circulating system is to be small; otherwise, the controlling resistance may be outside of the radiator core.

Effect of Water-Flow on Cooling-Capacity

The heat dissipation of a radiator core depends upon the rate of water-flow as shown in Fig. 10, which is reproduced from Bureau of Standards' Technological Paper No. 211. It will be seen that little is gained by increasing the water-flow beyond 18 gal. per min. for the core

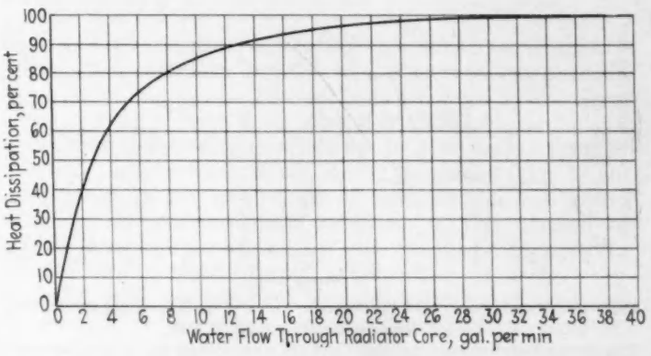

Fig. 10—Variation of the Cooling-Capacity of a Radiator Core with Water-Flow

It Will Be Seen That for Water-Flow Rates Exceeding 18 Gal. per Min., the Gain in Cooling-Capacity Is Slight. In General for All Types of Present-Day Cores, the Cooling-Capacity Is Not Materially Increased when the Rate of Water Flow Is More Than 3 Gal. per Min. per In. of Core Depth per Ft. of Width

shown, which was 2 ft. wide and 3 in. deep, or by increasing it beyond 3 gal. per min. per ft. of width per in. of depth of core. At higher water-velocities, the limiting factor is the heat-transferring ability of the air, but for lower water-flows than about 3 gal. per min. per ft. of width per in. of core depth, the cooling-capacity of the core is considerably affected by the water-flow, everything else remaining the same. From the curve given, it is easy to calculate the extent to which a thermosiphon system will handicap the radiator and reduce its cooling-capacity. For example, if the water-flow through a radiator is reduced from 10 to 2 gal. per min., everything else remaining the same, the heat dissipation will be reduced from 85 per cent of the maximum to 40 per cent; or, it will be reduced by more than 50 per cent. And, if the water-flow is 1 instead of 2 gal. per min., the heat dissipation will be only about 20 per cent of the maximum.

As to a comparison of the pump and the thermosiphon systems of circulation, it seems to me that the superiority of one over the other must be decided for each individual case by weighing all the advantages and the disadvantages of each system properly, assuming that they are known and understood and have reference not only to their effect on the cooling-capacity of the radiator but to the temperature of the cylinder-metal as discussed in the first part of the paper under the heading: Temperature-Drop in Cylinder-Metal, in Scale, in Air and in Water.

Road-Tests

Laboratory tests are very important, more flexible and better adapted than road-tests to the study and the improvement of design details and thus have a peculiar field of usefulness; but road tests are absolutely essential, since no car or truck can be placed in the hands of the public on the basis of laboratory experiments only, without actual road-tests under practical conditions of operation.

The best way to run road tests is to place, on the dashboard, long-distance-type thermometers connected with the engine so as to read

(1) Radiator-top tank-temperature, Θ_1
(2) Radiator-bottom tank-temperature, Θ_2
(3) Air temperature under the hood, t_3
(4) Temperature of the oil in the crankcase. This reading is not necessary, but it is very useful and important
(5) Temperature, t_1, of the air entering the radiator. This can be read by an ordinary thermometer placed in front of the windshield

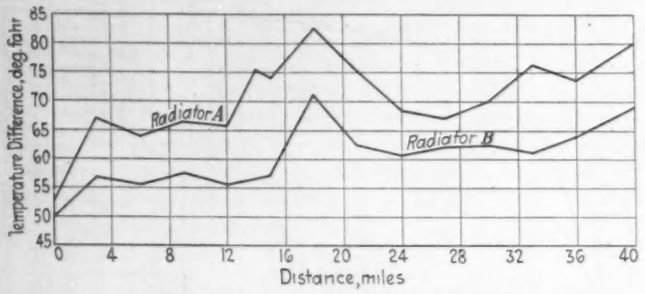

FIG. 11—ROAD-TESTS OF RADIATORS IN A 1½-TON TRUCK DRIVEN AT A UNIFORM SPEED OF 12 M.P.H.
The Tests Represented by the Curves Were Made on Two Consecutive Days and All Test Conditions Were Practically the Same Except the Outside Air Temperature Which Varied by about 8 Deg. As the Curves Show the Temperature Difference between the Cooling Water and the Radiator Air, This Variation Is Taken Care Of

The car, the tractor or the truck should be equipped consecutively with the various radiators to be tested, and should be run carefully under conditions that are as nearly identical as possible. The effect of the wind is very noticeable and it is necessary to make round trips to show the effect of this factor, which is, unfortunately, beyond control. Readings of the wind velocity and its direction can be made and used to make corrections; however, I have not found this necessary under ordinary weather conditions, provided the other readings are taken carefully and interpreted properly. Road tests can be made at very high speeds; at low speeds through sand and at high or low speeds up steep and long hills. The choice of the method of running road-tests will depend greatly on the locality, and each will give very valuable information as to the performance of the engine and its cooling. In general, the top tank-temperature is the controlling and limiting temperature in ordinary cooling systems, and these readings have therefore a peculiar importance and interest.

To determine the comparative cooling capacity of different radiators, curves should be plotted as shown in Fig. 11 in which the ordinates represent $\Theta - t$, the temperature difference between the mean water and the mean air-temperatures. This yields results practically identical with the logarithmic form, for the range of temperature we are interested in, although the latter is more correct theoretically. For example, let the following symbols and water and air-temperatures be used:

$t_1 =$ 80 deg. fahr. for the entering air
$t_2 =$ 110 deg. fahr. for the leaving air
$\Theta_1 =$ 200 deg. fahr. for the top tank
$\Theta_2 =$ 190 deg. fahr. for the bottom tank

Then, the arithmetic temperature-difference is

$$\Theta - t = [\tfrac{1}{2}(200 + 190)] - [\tfrac{1}{2}(80 + 110)]$$
$$= (195 - 95)$$
$$= 100 \text{ deg.}$$

The logarithmic temperature-difference will be

$$\frac{\Psi_1 - \Psi_2}{\log_e\left(\frac{\Psi_1}{\Psi_2}\right)} = \frac{(200 - 80) - (190 - 110)}{\log_e\left(\frac{200 - 80}{190 - 110}\right)}$$
$$= \frac{120 - 80}{\log_e (1.5)}$$
$$= \frac{120 - 80}{2.3 \log_{10} (1.5)}$$
$$= 98.7$$

However, I have found that unless the aerodynamic characteristics of the radiators to be compared are nearly alike, it is better to use $\Theta - t_1$ instead of $\Theta - t$.

A glance at Fig. 11 shows that the road tests were run under nearly identical conditions; the curves rise and fall together and are fairly similar in shape. Assuming that the heat rejected to the jackets from instant to instant was practically the same for both runs, we find that radiator A, after going over a small hill at a distance of 17 miles from the starting point, reached a temperature difference of 82.5 deg. fahr., while radiator B reached a 71-deg. fahr. temperature-difference. The cooling-capacity of radiator cores is indirectly proportional to $\Theta - t$, everything else, such as the airflow and the like, being the same. Hence, the cooling capacity of radiator B divided by the cooling capacity of radiator $A = 82.5/71 = 1.16$. In other words, radiator B has 16-per cent more cooling-capacity than radiator A. In this way we can compare these two radiators at other points and determine the average amount by which the cooling-capacity of radiator B exceeds that of radiator A.

The physical meaning of the curves of Fig. 11 is as follows: Since it was assumed in both tests that the amount of heat rejected to the jacket is about the same, from instant to instant, both radiators had about the same amount of heat to dissipate; and the one that did its work with a smaller temperature-difference between the water and the air $\Theta - t$ had that much more reserve capacity. Hence radiator B is superior to radiator A. The tests represented in Fig. 11 were made on two consecutive days, and all test conditions were practically identical except the outside temperature, which varied by about 8 deg. fahr. This variation, however, is taken care of in the curves, since these show the temperature difference, $\Theta - t$.

Another set of tests made on Westfield Hill, near Jamestown, N. Y., are shown in Fig. 12. The hill starts at the point marked 1 mile, on the x-axis, and is about 1.7 miles long. The car was tested by driving it at a uniform and constant speed of about 35 m.p.h. It is seen that radiator F reached a maximum temperature of 198 deg. fahr., while radiator J reached a temperature of 190 deg. fahr. This difference of 8 deg. fahr. in the top tank-temperatures is not a sufficiently clear indication, by itself, of the cooling-capacity of these radiators. In this case the slopes of the curves, shown in dash lines, are of great interest and have a definite physical meaning. They show the rise of Θ_1, the top tank-temperature, per mile of travel. In the case of radiator F we started with a temperature of 180 deg. fahr. and this was

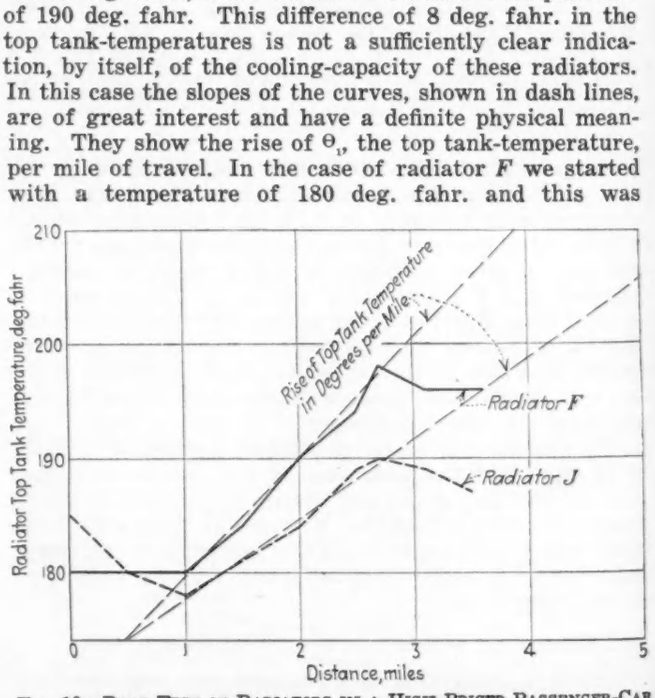

FIG. 12—ROAD-TEST OF RADIATORS IN A HIGH-PRICED PASSENGER-CAR
The Mean Slopes of the Curves, Shown by the Dash Lines, Are of Interest and Have a Definite Physical Meaning. They Show the Rise of the Top Tank-Temperature per Mile of Travel and Serve as a Basis for Readily Comparing the Cooling-Capacity of the Two Radiators

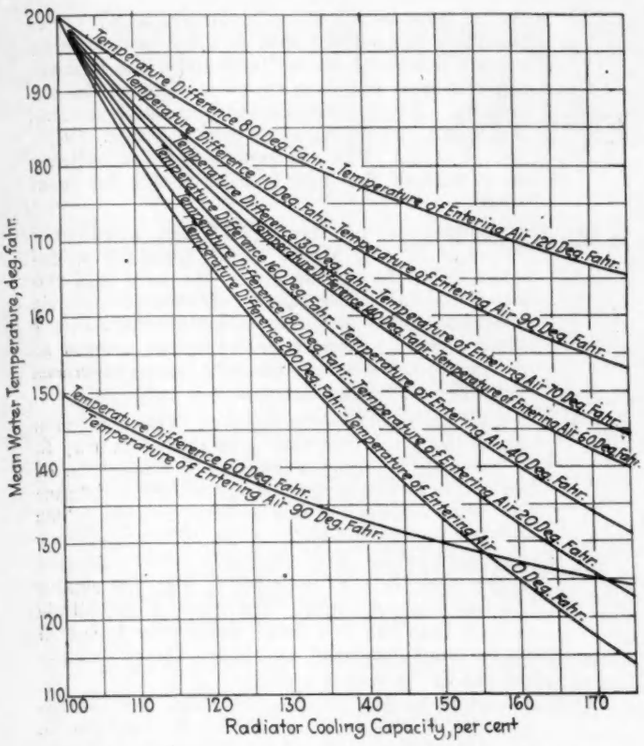
Mean Water Temperature, deg. fahr.
Radiator Cooling Capacity, per cent
Temperature Difference 80 Deg. Fahr. - Temperature of Entering Air 120 Deg. Fahr.
Temperature Difference 110 Deg. Fahr. - Temperature of Entering Air 90 Deg. Fahr.
Temperature Difference 130 Deg. Fahr. - Temperature of Entering Air 70 Deg. Fahr.
Temperature Difference 140 Deg. Fahr. - Temperature of Entering Air 60 Deg. Fahr.
Temperature Difference 160 Deg. Fahr. - Temperature of Entering Air 40 Deg. Fahr.
Temperature Difference 180 Deg. Fahr. - Temperature of Entering Air 20 Deg. Fahr.
Temperature Difference 200 Deg. Fahr. - Temperature of Entering Air 0 Deg. Fahr.
Temperature Difference 60 Deg. Fahr. - Temperature of Entering Air 90 Deg. Fahr.

FIG. 13—ENGINE-RADIATOR COOLING-CURVES AT VARIOUS TEMPERATURES FOR THE AIR ENTERING THE RADIATOR

maintained for a distance of 1 mile, which would indicate that the cooling-capacity of the radiator was equal to the heat rejected to the jackets. As we started up the hill, the amount of the heat rejected to the jackets was larger than the amount dissipated by the radiator; the heat in excess of the radiator capacity went on to increase the temperature of the water, the engine, the oil and the like. Suppose that the amount of heat not taken care of by the radiator was 640 B.t.u. per min. or 640 B.t.u. for every 0.58 miles, or 1100 B.t.u. per mile of travel. This amount was available to heat the water, the engine and the like, which we will assume as equivalent to 100 lb. of water. The mean increase in the temperature of this water equivalent will be (1100/100) = 11 deg. fahr. per mile, which equals the slope of the curve for radiator *F* in Fig. 12. As shown in the chart, if this hill were about 4 miles long, radiator *F* would have boiled.

Let us now consider radiator *J*. On the basis of the assumptions made above for radiator *F*, the excess heat per mile available to heat the engine and the water amounted to about 700 B.t.u. per mile or 400 B.t.u. per min., so that the rise in temperature per mile of travel is (700/100) = 7 deg. fahr.; and this radiator will need to travel 5.6 miles to boil, if the hill were long enough. Further, assuming that the total heat rejected to the jacket was, on the average, 1150 B.t.u. per min. or 2000 B.t.u. per mile of travel, we shall find that the heat dissipated by radiator *F* was (1150 — 640) = 510 B.t.u. per min.; for radiator *J* we get (1150 — 400) = 750 B.t.u. per min. Hence, the cooling-capacity of these radiators is as 750 is to 510, or as 1.47 is to 1.00. In other words, radiator *J* has 47 per cent more cooling capacity than radiator *F*.

The quantitative results reached in the above discussion of Fig. 12 were based mostly on assumptions the correctness of which is not guaranteed, but I trust that they give a clear idea, both qualitative and quantitative, of the cooling process and illustrate the physical meaning of the curves plotted from the road tests. They checked very closely with laboratory tests.

Lack of space will not allow me to give more examples of road tests I have made, but the temperature readings given in the beginning of this section will prove sufficient to answer most questions if the method of taking readings is varied to suit the problem and the results are correlated and interpreted properly. Ordinarily, road tests cannot be made with great accuracy, though all the accuracy required for practical purposes can be secured by correlating engine block-tests, road-tests and laboratory-tests of fans, radiators and pumps. In most cases, it is not great accuracy that it is needed so much as a simple reliable method of determining whether or not a car, a truck or a tractor is cooled properly; whether or not it is cooled better than the previous model and whether or not different changes in the fan, the radiator and the hose connections have affected the cooling. These and similar questions can be answered by the road tests outlined.

ROAD AND LABORATORY TESTS

In laboratory tests, radiators are compared on the basis of their cooling-capacity, or on the basis of the number of British thermal units per minute dissipated per 100-deg. fahr. temperature-difference per square foot of frontal area, at a given air-velocity. In road tests, usually, only temperature readings are available; therefore, it seems desirable to have some convenient means of showing the relation between these two. Figs. 13 and 14 give curves that attempt to do this. For example, let the mean water-temperature of a radiator be 200 deg. fahr. when t_1 the entering air-temperature is 90 deg.

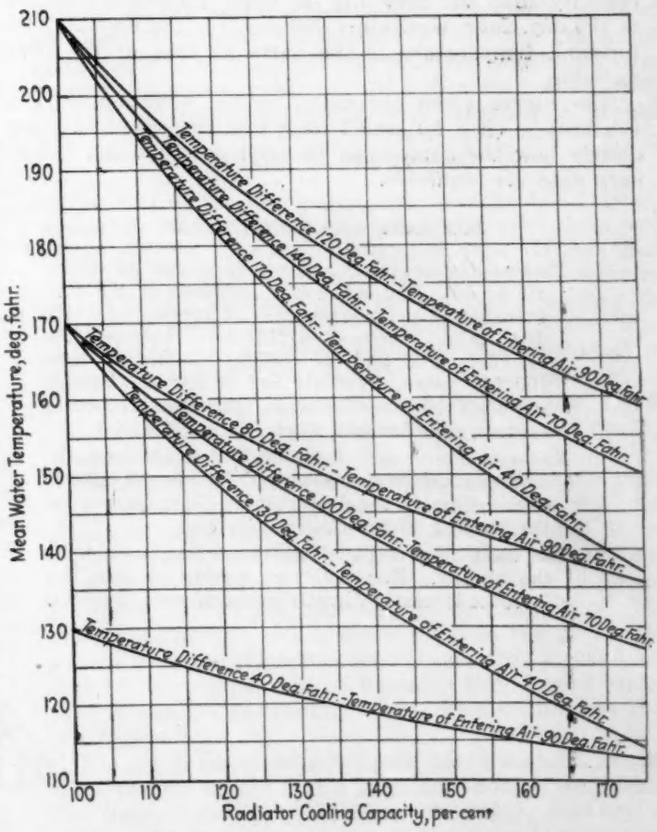
Mean Water Temperature, deg. fahr.
Radiator Cooling Capacity, per cent
Temperature Difference 120 Deg. Fahr. - Temperature of Entering Air 90 Deg. Fahr.
Temperature Difference 140 Deg. Fahr. - Temperature of Entering Air 70 Deg. Fahr.
Temperature Difference 170 Deg. Fahr. - Temperature of Entering Air 40 Deg. Fahr.
Temperature Difference 80 Deg. Fahr. - Temperature of Entering Air 90 Deg. Fahr.
Temperature Difference 100 Deg. Fahr. - Temperature of Entering Air 70 Deg. Fahr.
Temperature Difference 130 Deg. Fahr. - Temperature of Entering Air 40 Deg. Fahr.
Temperature Difference 40 Deg. Fahr. - Temperature of Entering Air 90 Deg. Fahr.

FIG. 14—ANOTHER SET OF ENGINE-RADIATOR COOLING-CURVES

fahr. Taking this radiator capacity as 100 per cent, let it be required to find the size of core that will reduce the water-temperature from 200 to 190 deg. fahr. According to the curve of 110-deg. fahr. temperature-difference and an entering-air temperature of 90 deg. fahr. the core capacity required is 110; that is, the cooling-capacity of the second radiator, under the same actual road conditions, should be 110 per cent of the first radiator; if there is any difference in air or water-flow, allowance for these must be made separately. For example, suppose that the water-flow for the first radiator is 100 lb. per min. and the temperature-drop across it is 10 deg. fahr. so that its cooling-capacity is $10 \times 100 = 1000$ B.t.u. per min.; then, for the second radiator we shall have $11 \times 100 = 1100$ B.t.u. per min. or $10 \times 110 = 1100$ B.t.u. per min., according to whether the temperature-drop is 11 or 10 deg. Thus the top and the bottom tank-temperatures will be 205.0 and 195.0 deg. fahr. for radiator No. 1, and 195.5 and 184.5, or 195 and 185 deg. fahr. for the second radiator, according to whether the temperature-drop $\Delta\Theta$ is 11 or 10 deg. fahr.

The car, truck or tractor designer is more interested in the top tank-temperature than in the mean temperature used in the above example and, if the temperature-drops are the same, the ordinates of the Figs. 13 and 14 can be taken as equal to Θ_1. However, it is best to calculate the top tank-temperature separately as it was done above. To illustrate this more clearly, however, let us assume a larger temperature-drop. Let 1100 B.t.u. per min. = 20 deg. fahr. temperature-drop times 55 lb. per min. water-flow. In this case, $\Theta = 190$ deg. fahr. and the radiator capacity is 110 per cent of the first one as before, but the bottom tank-temperature is 180 deg. fahr. and the top tank-temperature is 200 deg. fahr.; that is, the second radiator has 10 per cent more cooling-capacity than the first and its mean water-temperature is 190 deg. fahr. as against 200 deg. for the first, but its top-tank temperature is the same as that of the first radiator.

The curves given are based on the equation $H_d = \text{a constant} \times (\Theta - t_1)$, and I trust that the examples show clearly how the curves can be used provided the necessary data are available.

Summary and Conclusions

1) Present-day engine-cylinders are cooled by water, air or oil. The order of magnitude of the heat transferred per square inch of surface per 100-deg. fahr. temperature-difference between the cylinder-metal and the cooling medium is about 100 for water, 1 for air and 10 for oil, depending upon the rate of flow, its turbulence and other factors, as is brought out in Figs. 1, 2 and 3

(2) Radio-condenser or steam cooling of water-jacketed engines is discussed and its alleged advantages given in the first part of the paper under the heading Steam-Cooling Systems

(3) The cooling-capacity of radiators increases with the airflow. For radiators having no fins, the increase is nearly directly proportional; doubling the airflow doubles the cooling-capacity. For radiators having fins, that is, an indirect cooling surface swept by air on both sides, the cooling-capacity does not increase so rapidly as the air velocity. Expressing the above in mathematical shorthand, we obtain: $H_f = \text{a constant } (v_a)^n$. (See Fig. 5.) The exponent $n = 1$ for radiator cores without fins and $n = 0.5$ to 0.9 for most others

(4) The amount of air flowing through a radiator traveling in still air at a car speed of v_f depends upon the resistance of the core and the resistance in the remainder of the air circuit under the hood. Two curves are given in Fig. 7 which show, as percentages of v_f, the amount of airflow at various aerodynamic head-resistances and different pressure-drops

(5) The amount of airflow induced by a fan depends on the design of the fan, as is shown in Fig. 8. In general, a propeller or curved-blade type of fan will draw more air through a high-resistance core than through a low-resistance core. The opposite is true for a disc type of fan

(6) In engines having pump circulation, the resistance of the core is not, in general, the controlling resistance in the circuit. Its order of magnitude is such that the frictional water-flow losses in the bottom tank-outlet, in bends, elbows and the like are by no means negligible

(7) For engines having pump circulation, the cooling-capacity of the radiator begins to decrease as the rate of flow begins to fall below 3 gal. per min. per ft. of width per in. of thickness of the core. (See Figs. 9 and 10.)

(8) An allowance of 5 cu. in. of radiator core per cubic inch of piston displacement should be made for cooling passenger-car engines. More radiator capacity should be allowed for trucks and tractors, particularly if the fin-and-tube type of core is to be used. Another way to estimate radiator capacity is to assume that the heat rejected to the jacket is equal to the brake horsepower developed by the engine. I have found both of these to give satisfactory results in practice, but it is understood that estimates of this kind are general and should be checked by road tests

(9) In making road-tests, temperature readings Θ_1, Θ_2, t_1 and t_2 should be taken every ½ mile or so, by long-distance-type thermometers. These can be plotted as indicated in Figs. 11 and 12 and interpreted as outlined in the second part of the paper under the heading of Road-Tests

(10) Relations between cooling-capacity of radiators and the top and the bottom tank-temperatures are given in the curves of Figs. 13 and 14. By means of these curves, it is possible to answer such questions as: If a radiator under certain conditions of road-test reaches a temperature of 200 deg. fahr., how much larger a radiator will be required to reduce this temperature to 190 or 180 deg. fahr.? This is discussed in the second part of the paper under the heading Road and Laboratory Tests

Systematic Gage-Checking as a Requisite of Precise Measurement

By JOSEPH LANNEN[1]

ANNUAL MEETING PAPER

DUE to an increasing number of arguments and a constantly increasing volume of scrapped and salvaged material on account of the use of faulty gages, the company with which the author is associated was led to adopt a systematic gage-checking system and to install a separate gage-checking department. This was occasioned also by the growth of the business from one that produced a comparatively few cars into one capable of turning out 300 cars daily. During this growth the company experienced all phases of the gage-checking problem.

Details are given of the methods employed in creating and maintaining a gage-checking system, and a statement is made in reference to the equipment used and the good results that have been attained.

IT is an axiom that accurate gaging is the basis of interchangeable manufacture. To secure accurate gaging, it is necessary that gages of the requisite degree of precision be employed and that they be checked at suitable intervals to maintain this accuracy. The problem of maintaining such accuracy is relative to the size of the plant and to the volume and the type of work to be checked. In a small plant that does rough work, scales and calipers may constitute the entire gaging equipment. Instances of the other extreme are found in gun shops or watch factories that use hundreds of extremely accurate gages. Between these extremes lies the automobile plant and, in the automotive industry, the relative importance of accurate gaging varies with the number and the quality of the cars produced.

In the past few years the company I represent has grown from one that produced a comparatively small number of cars into one that is capable of building 300 cars daily. In the interim, the company has experienced the various phases of the gage-checking problem. As the size of the plant increased, an increasing number of arguments with outside sources of supply developed and a constantly increasing volume of scrapped and salvaged material was produced, due to the use of faulty gages. A number of half-hearted attempts had been made to correct this condition by making the inspection department of the toolroom responsible for the checking of gages. But the results were that, when the inspection department was responsible for the gage-checking, it took care of its own gages but neglected the gages belonging to the shop; and when the toolroom was responsible, it neglected this work when pressed with work from other sources.

The shop's engineering department was requested to take over this problem about 2 years ago, and an investigation disclosed the conditions just described. At the outset, we were fortunate in securing the services of a man who was a good accurate mechanic, one who had a good knowledge of shop conditions and who recognized the importance of service. With his aid, we developed a satisfactory method of gage-checking.

[1] Tool and equipment engineer, Paige-Detroit Motor Car Co., Detroit.

THE GAGE-CHECKING DEPARTMENT

To begin the installation of a gage-checking department, it is necessary first to locate the gages, then to provide means for identifying each gage, then to cull out all unused and inaccurate gages, then to check them at stated intervals and finally to keep a record of the actual measured size of each gage as it is checked. At the time we installed the gage-checking department a large accumulation of gages was scattered throughout the plant and in the various cribs. A considerable percentage of these were gages that had been used on obsolete models and that had been allowed to remain in circulation after these models had been discontinued.

At first, it appeared necessary to make a list of all standard gages required for the inspection of each part, and we were about to make such a list when a simple expedient was devised which made this work unnecessary. The plan adopted was to check every standard, snap, plug and thread gage that could be found in the plant. The gages that were inaccurate were withdrawn from circulation, and those that were up to size were numbered. Each gage of a certain size was given a consecutive number; thus, if there are four 0.375-0.374 plug gages, they were given numbers from 1 to 4 and a card was issued for each one that showed the nominal size of the gage, its number, its location in the plant, the actual measured size of the gage and the date on which it was checked. They were then given a thin coat of Prussian blue on the gaging faces and were returned to circulation.

GAGE IDENTIFICATION

The loss of the live gages that were held out due to inaccuracy was soon felt by those who used them and, where possible, they were replaced at once. If they were not too badly worn, they were painted red and were returned to the workmen who needed them, pending the arrival of accurate gages. A gage that showed wear of 20 per cent of the given tolerance was considered inaccurate; thus, a 0.3750-0.3740 plug-gage would be replaced when the "go" member is worn below 0.3738. This allowance for wear has proved to be satisfactory in the majority of cases.

The object of coating the wearing faces of the gages that were in circulation with Prussian blue was that, after the gages had been checked and numbered, it was evident that those which were still blue had not been used, when a weekly check was made on all gages; therefore, it was not necessary to recheck them. This saved considerable unnecessary work on the part of the gage checker. If, after several months, a gage still showed its original coat of Prussian blue, it was evident that it was not in use and it was then withdrawn from circulation.

The gages are blued after each periodic check, because it frequently occurs that a gage may not be used during the time intervening between checkings. Another advantage arising from the use of Prussian blue on gages

is that it occasionally happens that the shop or inspection department will neglect to use a gage where specified. This is evidenced by the Prussian blue that remains on the gage. When a condition of this nature is discovered by the gage checker, it is his duty to report it to the proper authorities.

Features of Systematic Checking

The foregoing is an outline of the method employed in the installing of the gage department, but after it was in operation and its possibilities came into evidence a number of additional features were incorporated which resulted in increasing the service feature of this department. It soon became apparent that it would be an advantage to all concerned if everything possible pertaining to gages could be concentrated in the gage-checking department. It was with this idea in mind that all obsolete and undersize gages were stored in this department as well as the reserve supply of new gages that had formerly been kept in the tool stores department. We have standardized so far as possible on Johansson built-up plug-gages, standard adjustable snap-gages and standard thread snap-gages with interchangeable gaging members. This standardized gaging equipment enables the gage-checking department to build-up a great many gages directly from its stock.

The plug-gages consist of a handle to which are attached reversible "go" and "not go" gaging members. This, of course, limits the number of combinations that can be secured from the stock of plugs. But, with the adjustable snap-gages, it is possible to secure any combination of sizes within the range of the various standard gage bodies.

Repairs

A record is kept of the various sizes of gage in stock. A request for a new gage, whether for use on the product being manufactured or for a new part, comes to the gage-checking department; there, the request is checked against the record of the gages in stock and also against the record of gages in use to determine if a new gage is necessary. If a new gage is needed it is ordered by the gage-checking department.

Repair parts are kept in stock for micrometers, amplifiers, dial indicators and scleroscopes. The repairs on these are made by the gage-checking department. The volume of up-keep work on this type of equipment is surprising, one man being kept on this work practically all the time. This is, of course, a saving in both time and money, when compared with the previous practice of returning these instruments to the manufacturers for repairs.

Employes' micrometers are inspected and adjusted on request. Micrometers belonging to the company are checked periodically in the same manner as for standard gages. Scleroscopes used in checking the product are cleaned daily. This is necessary to assure accurate readings, because the hammer fits very closely in the glass tube and the presence of a very small quantity of dust will impair the accuracy of these instruments. Special gages and inspection fixtures are checked periodically in the same manner as plug and snap-gages. When they are found to be inaccurate, an order is issued to the toolroom to make the necessary repairs. These orders are followed-up by the gage-checking department, and, when the repairs are completed, the gage is returned to service at once.

An additional duty, though not strictly a gage-checking proposition, taken on by this department is the checking of gear-cutting hobs. The importance of having accurate gear-cutting hobs cannot be emphasized too strongly. Commercial hobs are made today to a limit of error in lead, from tooth to tooth, of ± 0.0002; and, in lead, the tolerance is 0.0005 per convolution. Due to the fact that delicate instruments and careful checking are required on these tools, this work was turned over to the gage-checking department, which checks every hob when it is received from the manufacturer. A record is kept of the error in each tooth and the errors in the lead. The size of the hole for the arbor is checked also. After each grinding, the gashing is checked to assure accuracy of spacing and radialism, since these must be extremely accurate if all of the hob teeth are to be kept to equal heights.

Records

When the gage-checking department was installed, it was our aim to keep the record work as simple as possible; so, we began with a card for each gage, as previously mentioned. On this card is a description of the gage, its type, its nominal size and the minimum size to which it may wear before being scrapped. Space is provided to record the number of the department or crib where the gage is located; a number of spaces are provided also to record the dates on which the gage is checked, its actual size at the time of checking and the signature of the checker. These spaces are continued on the reverse side of the card.

The cards are grouped in a file under the headings of "gages in service," "obsolete gages," and "salvage gages." Under the heading of obsolete gages come all gages that are not used because the parts for which they were ordered have been discontinued or changed. Under the heading of salvage gages are filed the record cards whose gages have been ground to a smaller size or dismantled and returned to stock; a note on the card tells how the gage was disposed of. A record card is also kept for each size of gage; these cards are filed according to the size and the type and list every part on which each gage is used. These record cards are used to determine the number of gages of a given size that are required for production; they also aid in locating gages when only their sizes are known. The gages kept in stock are also listed for convenience in locating them.

Gage-Checking Equipment

The gage-checking department is supplied with the following equipment: A surface plate; bench centers; a ground angle-plate; a square; a pair of "V" blocks; a pair of cubes; four pairs of parallels; a height gage; a 24-in. vernier caliper; a set of micrometers, 1 to 6 in.; a set of arbors; a set of Johansson blocks; two indicators; a sine bar and all necessary clamps and fixtures required for checking purposes.

With this equipment, two men have taken care of approximately 1600 pieces of gaging equipment that are used in checking the parts made by our company. Since this gage-checking department has been established, no work has been rejected by the machine shop on account of faulty gages and, where gages are concerned, a feeling of comfortable security in regard to accuracy prevails. Though it is difficult to place a monetary value on this type of service, we do know what it costs to assure accurate gaging equipment and we believe that it pays for itself, to say nothing of the fact that it aids in producing a finer product.

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Practical Balancing of a V-Type Engine Crankshaft

By D. E. Anderson[1]

Detroit Section Paper *Illustrated with* Photographs and Drawings

SUPPLEMENTING a paper by another author that treats the theoretical balancing of this engine, Mr. Anderson presents the practical methods that have been devised to accomplish the results desired. Since this crankshaft is not in running or in dynamic balance without its piston and its connecting-rod assemblies, it is necessary to apply equivalent weights on each of the crankpins when balancing it on a dynamic balancing-machine and details are given of how these weights are determined.

The selection of parts to obtain equal weights is also necessary; a description is given of how this is made. A combination static and dynamic balancing-machine that can be set for either operation is used for balancing the crankshaft. Details of its operation are presented. Service conditions to secure parts replacements within the weight limits specified are outlined, and flywheel, universal-joint assembly and other unit balancing is discussed. The method of testing the completed work is stated. Tabular data accompany the text.

ENGINE balancing to eliminate vibration has been given a great amount of study by engineers and production men and all phases of the subject have been investigated thoroughly. The theoretical side of this problem was covered by E. W. Seaholm, in his article on Balance of the Cadillac V-63 Engine.[2] This paper has to do with the production of the crankshaft of that engine, especially in regard to the methods used in balancing it. Without the piston and the connecting-rod assemblies this crankshaft is not in running or in dynamic balance, as Mr. Seaholm pointed out. Therefore, it is necessary to apply equivalent weights on each of the crankpins when balancing it on a dynamic balancing-machine. The first question that arose was: What shall this weight be? Theoretically, this weight should be equal to the sum of the rotating parts, plus one-half of the reciprocating masses. This sounds simple enough, but does not include consideration of the variations in the weight of the various parts as manufactured. To determine these variations, numerous parts were weighed. When these weights were tabulated, it was apparent that the assemblies would have to be aggregated by selection to obtain a certain combined weight, within reasonable limits.

The value of the balancing-ring weight was determined finally by taking 10 complete sets of parts, carefully machined to the mean limits, and averaging their weights. Fig. 1 shows the method used in calculating this weight from the average weights of the various parts. The weight shown in Fig. 1 is correct for the shaft as assembled in the engine and with the engine running; in other words, with the shaft completely filled with oil. The counterweights are designed while taking into consideration the weight of the crank-cheeks, the crankpins, the oil in the pins and the plugs used to close-up oil-channels, as well as considering the unbalanced centrifugal couple caused by the weights mentioned above, as applied to the crank-throws. It was found impracticable to fill each shaft with oil before balancing, as all oil-holes would have had to be plugged-up and the shaft filled with oil, this requiring a considerable amount of time; also, such an operation would necessitate painstaking care to ensure having the proper amount of oil in the shaft while balancing it. In lieu of the oil and the end-plugs, additional metal had to be added to the balancing weights; this amounts to 0.276 lb. and makes their final values 114 oz. each.

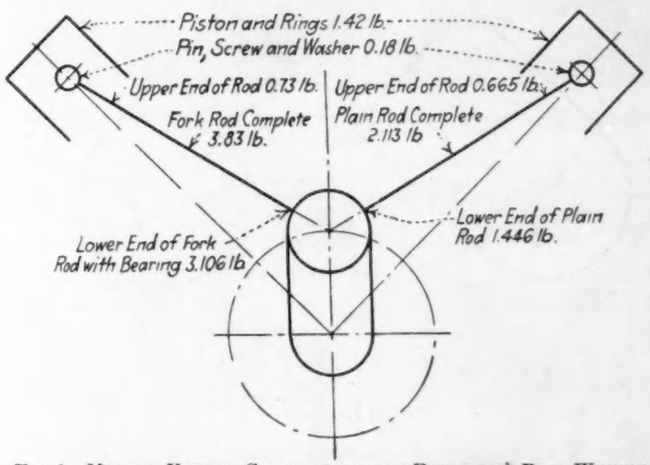
Piston and Rings 1.42 lb.
Pin, Screw and Washer 0.18 lb.
Upper End of Rod 0.73 lb.
Fork Rod Complete 3.83 lb.
Upper End of Rod 0.665 lb.
Plain Rod Complete 2.113 lb
Lower End of Plain Rod 1.446 lb.
Lower End of Fork Rod with Bearing 3.106 lb

Fig. 1—Method Used in Calculating the Balancing-Ring Weight from the Average Weights of the Various Parts

The Weight Shown Is Correct for the Shaft as Assembled in the Engine and With the Engine Running, in Other Words with the Shaft Completely Filled with Oil. The Counterweights Are Designed Taking into Consideration the Weight of the Crank Cheeks, Crankpins, Oil in the Pins and the Plugs Used to Close the Oil Channels as Well as the Unbalanced Centrifugal Couple Caused by the Weights Mentioned Above, Applied to the Throws

Fig. 2 illustrates the balancing weight just referred to. As was pointed out before, it is necessary to apply

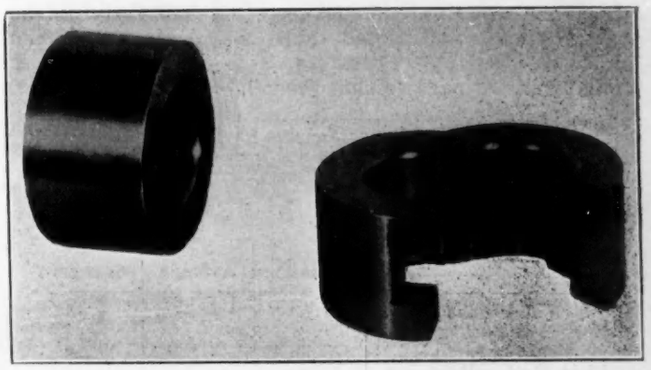

Fig. 2—One of the Ring Balancing Weights

One of These Weights Is Applied to Each Crankpin before the Crankshaft Can Be Correctly Balanced, Since These Weights Represent the Rotating and the Reciprocating Parts That Are Compensated For in the Completed Engine by the Counterweights

[1] M.S.A.E.—Designing engineer, Cadillac Motor Car Co., Detroit.

[2] See The Journal, January, 1924, p. 70.

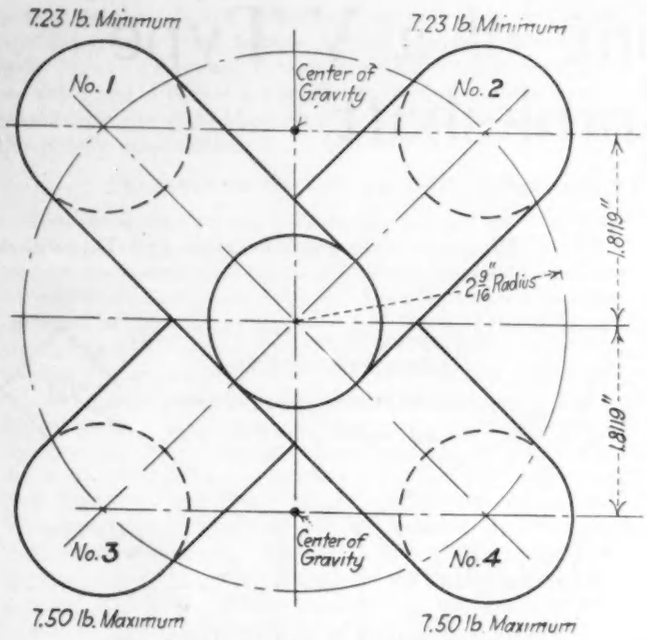

FIG. 3—AN EXAMPLE OF STATIC UNBALANCE

In This Hypothetical Case, in Which Two Minimum-Weight Assemblies Were Selected for Crankpins Nos. 1 and 2 and Two Maximum-Weight Assemblies for Crankpins Nos. 3 and 4, a Possible Static Unbalance of 15.65 Oz-In., or Nearly 1 Lb. at a 1-In. Radius Resulted

one of these balances on each crankpin before it is possible to balance the crankshaft correctly, as these weights represent the rotating and the reciprocating parts that are compensated for in the completed engine by the counterweights. A considerable amount of time and thought had to be put on the design and the manufacture of these rings, for the following reasons:

(1) Their weights must be equal

(2) They must be constructed so that application to the shaft will require the minimum of time

(3) It is necessary to have them hardened to withstand wear and possible deformation, if accidently dropped, and to prevent their becoming nicked by contact with some hard object

(4) They must be in static and dynamic balance so that their centers of gravity will lie exactly on the center-line of each crankpin and also in the correct axial position on the shaft

SELECTION OF PARTS TO OBTAIN EQUAL ASSEMBLY WEIGHTS

Referring to Table 1, it will be seen that the variations in the weight of such rotating and reciprocating parts as are compensated for in balancing are of considerable moment. Therefore, it is obvious that selections must be made so that the combined weight of each assembly that goes into a given engine is the same, within practicable limits; otherwise all advantage derived from balancing would be of no avail. For example, let us consider an hypothetical case in which we select two minimum-weight assemblies for the No. 1 and No. 2 crankpins and two maximum-weight assemblies for the No. 3 and No. 4 cranks. Fig. 3 illustrates this example and shows a possible static unbalance of 15.65 oz-in. or nearly 1 lb. at a radius of 1 in. This amount of error would produce a noticeable vibration.

In view of the weight inequalities of the different parts as manufactured, we had to evolve a process of selecting the various parts that make up an assembly. Even though these units are machined all over, it was found commercially impracticable to hold the various machine operations to such limits that equal weights would be obtained. The results produced by our method will not vary more than $\pm$ 1/8 oz. for each assembly. With this small variation, we have found it practicable to select combinations of such equality that the differences in the weight of the four complete piston and connecting-rod assemblies that go into the same engine will not be more than 1/8 oz.

TABLE 1—PARTS WEIGHTS TO OBTAIN EQUAL ASSEMBLY-WEIGHTS

Parts	Weight, Lb.		
	Minimum	Average	Maximum
Piston and Rings	1.38	1.420	1.46
Fork-Rod, Bushing, Bearing, Bolts, etc	3.78	3.830	3.88
Plain-Rod, Bushing, Bolts, etc	2.07	2.115	2.16
Total	7.23	7.365	7.50

TABLE 2—MAXIMUM, AVERAGE AND MINIMUM COMBINATIONS

	Lb.
Plain-Rod Combination	
Heavy Piston Assembly	1.46
Light Plain-Rod	2.07
	3.53
Average Piston Assembly	1.420
Average Plain-Rod	2.115
	3.535
Light Piston Assembly	1.38
Heavy Plain-Rod	2.16
	3.54
Fork-Rod Combinations	
Heavy Piston Assembly	1.46
Light Fork-Rod	3.78
	5.24
Average Piston Assembly	1.42
Average Fork-Rod	3.83
	5.25
Light Piston Assembly	1.38
Heavy Fork-Rod	3.88
	5.26

To facilitate selection, each part is weighed and marked in hundredths of a pound, accurate within 0.004 lb.; then these parts are stacked-up in piles according to weight. The assembler has a chart from which he can pick out the proper combination of weights to make up a complete assembly. Table 2 gives the information contained on the chart; it shows also the possible maximum and minimum combination. However, as each part is marked according to the nearest hundredth of a pound, there is a possibility of a greater number of combinations. **Therefore, Table 3 is followed.** The selection has now dwindled to three combinations for each assembly, and these are stacked accordingly.

In making the final assembly, composed of a complete plain-rod assembly and a complete forked-rod assembly, Table 4 is used. From Table 4 it is evident that the greatest possible variation between assemblies will be 0.02 lb. or 0.32 oz. In actual practice the variations are even less, being not more than 1/8 oz.

TABLE 3—SELECTION OF ASSEMBLY INSTRUCTIONS

Select	Weights, Lb.		
	Minimum	Average	Maximum
Piston Assembly and Fork-Rod Assembly To Weigh	5.22	5.250	5.28
Piston Assembly and Plain-Rod Assembly To Weigh	3.51	3.535	3.55

TABLE 4—FINAL ASSEMBLY SELECTION

Assembly	Weight, Lb.
Minimum Plain-Rod	3.51
Maximum Fork-Rod	5.28
	8.79
Average Plain-Rod	3.535
Average Fork-Rod	5.250
	8.785
Maximum Plain-Rod	3.55
Minimum Fork-Rod	5.22
	8.77

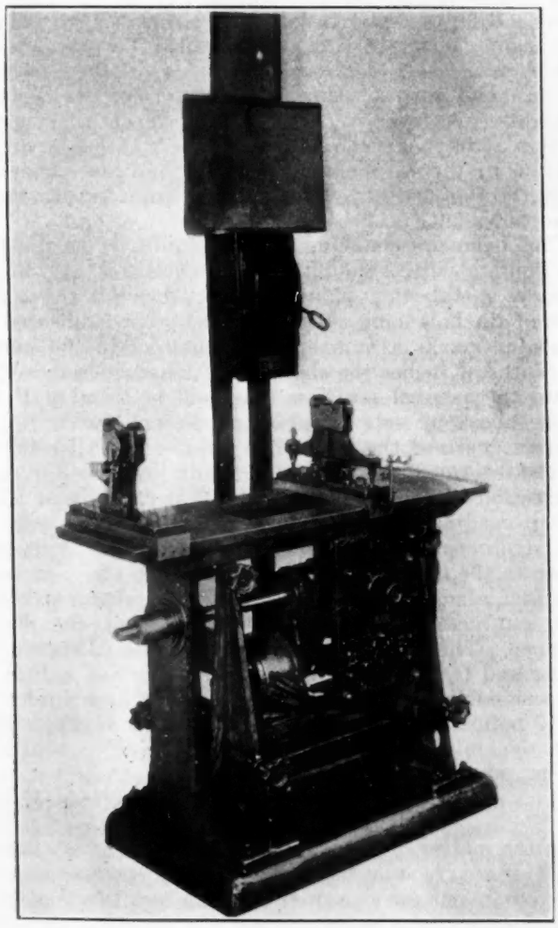

FIG. 4—TYPE OF MACHINE USED FOR BALANCING THE CADILLAC CRANKSHAFT

This Machine Is a Combination Static and Dynamic Balancing Machine and Gives the Plane of Unbalance and the Amount of Correction To Be Applied to the Shaft. Two of These Machines With Two Operators and One Helper Handle Over 100 Crankshafts Daily

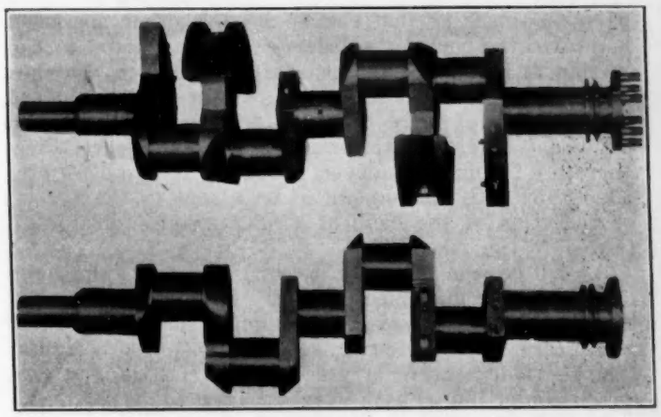

FIG. 5—A CRANKSHAFT WITH AND WITHOUT THE COUNTERWEIGHTS IN PLACE

The Crankshafts and the Counterweights Are Machined All Over. Four of the Latter, Two Large and Two Small, Are Applied to the Shaft and Great Care Is Exercised in Selecting Balanced Weights, Those in Which the Center of Gravity Falls on the Geometric Centerline of Each Weight. This Gives a More Nearly Correct Initial Static Balance

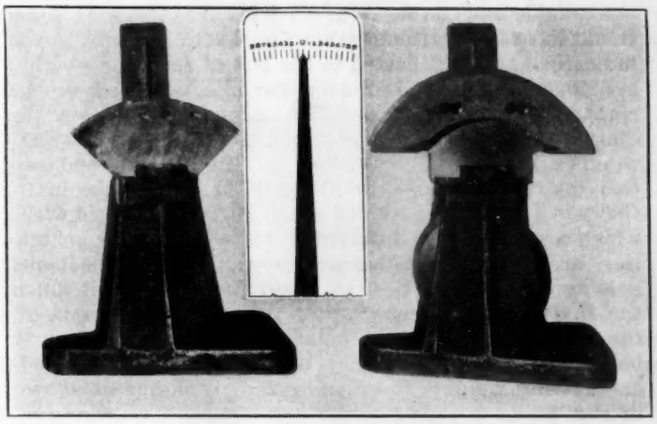

FIG. 6—EQUIPMENT USED FOR BALANCING WEIGHTS

BALANCING OF THE CRANKSHAFT

Fig. 4 shows the type of machine used for balancing the crankshaft. It is a combination static and dynamic

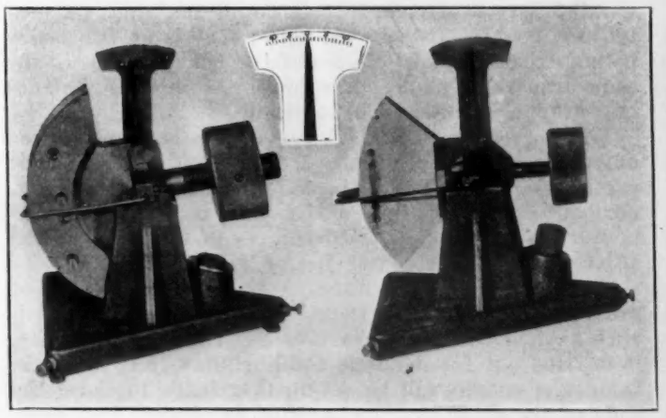

FIG. 7—OTHER FIXTURES USED FOR SELECTING WEIGHTS

The Threaded Weight Is Adjusted to the Position Found Best, That Is, a Point Corresponding to a Mass That Is Slightly Heavier Than What Is Theoretically Correct. When a Heavier Weight Is Used, Stock Can Be Removed from It. Otherwise, Metal Would Have To Be Ground from the Shaft. As Long As the Indicator Is Deflected to The Left of the Zero the Weights Are Satisfactory; If a Weight Deflects the Indicator to the Right, It Is Rejected. The Numbers on the Dial Correspond to Those Stamped on the Weights and the Counterweights Are Paired According to the Figures Stamped Thereon

balancing-machine that can be set for either operation, and gives the plane of unbalance and the amount of correction to be applied to the shaft. Two such machines are used. With three men, two operators and one helper, a production of more than 100 crankshafts per day is handled. After a little training and experience, these operators become very expert; they are able to determine almost instantly the amount of unbalance by the amount of deflection of the hand of a micrometer indicator attached to the machine.

As will be seen from Fig. 5, our crankshafts and counterweights are machined all over. Four counterweights, two large and two small, are applied to the shaft and great care is exercised in selecting balanced weights; that is, their centers of gravity must fall on the geometric center-line of each weight. This makes the initial static balance more nearly correct.

Fig. 6 shows the type of equipment used for balancing weights. Other fixtures are used for selecting weights as shown in Fig. 7. The threaded weight is adjusted to a position found best; that is, at a point corresponding to a mass which is slightly heavier than one that is theoretically correct. When a heavier weight is used, stock is available and can be removed from it; otherwise metal would have to be ground from the shaft. So long as the indicator hand is deflected to the left of zero, the weights are correct; if the indicator hand is deflected to the right, they are rejected. The numbers shown on the dial are the ones marked on the weights. Counterweights are paired according to the figures stamped thereon. When counterweights are fastened to the shaft, they are imprinted with the shaft serial number; dowels, which are located at different distances from the center-line, are used to preclude any possibility of a mechanic getting them on in a position other than the one in which the shaft was balanced. After the weights are applied, the shaft is placed in the balancing machine. It is first balanced statically and then dynamically, with the balancing-ring weights in place on the crankpins as shown in Fig. 8.

Static and Dynamic Balance

Static balance means a condition of balance such that the center of gravity of a body lies exactly on the axis of rotation; in other words, that there is no heavy point which would cause the body to roll over if placed on parallel ways. Dynamic balance means that no centrifugal couple exists in the body; that is no two heavy points exist on opposite sides of the body and not in the same transverse plane. A body can be in static balance but still be unbalanced dynamically.

The correction for static unbalance can be applied anywhere along the length of the body, but it is made preferably in the plane through the center of gravity, normal to the axis of the body, or as near this plane as is practicable; in other words, on one of the crank cheeks adjacent to the center bearing.

The nearer the correction is made to the center of gravity, the less will be the disturbance of dynamic balance. After the shaft has been put into static balance, it is tried out for dynamic equilibrium. If it is not in balance, a couple will be set-up that tends to cause the ends of the shaft to travel around in circles; but, since the left end of the shaft is supported in a rigid bearing and the right-hand end-bearing only is free to oscillate, this couple will cause the right-hand end to oscillate in practically a horizontal plane about the stationary support.

To correct for dynamic unbalance, it is necessary to introduce a centrifugal couple that is equal in magnitude but opposite in direction to the one manifested by the machine. This is done, practically, by removing an equal amount of metal from two places, one on either side of the center main-bearing and equidistant from it, and in the longitudinal plane indicated by the balancing clamp. The nearer to the ends this correction is made, the less metal will have to be removed, as the magnitude of a centrifugal couple is determined by the product of one of the weights multiplied by the distance between them. On the crankshaft under consideration, the end counterweights are operated upon for dynamic unbalance and the intermediate counterweights are drilled for static unbalance. Our weights are purposely made heavy to allow for metal to be removed by drilling into them; otherwise metal would have to be removed from the shaft proper, which would spoil its appearance and would require more time because this metal would need to be ground off. We have found the drilling method best, as it eliminates all guess-work.

Amount of Metal Removed

The amount of metal to be removed is determined as follows: A clamp having an adjustable 5-oz. weight is applied at the front end of the shaft; it can be swung around readily and clamped in any desired position. In practice the plane of unbalance always comes at approximately the same position within fairly close limits, since our crankshafts and counterweights are machined all over. By measuring the distance from a fixed point on the clamp to the movable weight, the amount of metal to be removed is determined, in terms of the depth of a ¾-in. drill on the outside diameter of the counterweights. A large vertical drilling machine is set up between the two balancing-machines. It has a dial attached to the feed mechanism that indicates the exact depth being drilled. This machine and its attachment are shown in Fig. 9.

The balancing-machine operator indicates on the counterweights with a height gage the position at which to remove metal, this plane running through the center-line of the balancing clamp. At the points indicated, the operator marks a number corresponding to the number of tenths of inches the clamp weight had been moved out from the neutral position. As will be seen in Fig. 9, there are four sets of graduations, calibrated for the correct depth of the drill when applied to either the end or the intermediate weights, for both static and dynamic corrections. The figures on the dial correspond to the clamp reading numbers; therefore, it remains only for the drilling-machine operator to bring the drill point down to the mark indicated and throw in the feed; when the dial reading corresponds to the number marked on the counterweights selected for correction, the drill is stopped. The shaft is then placed on the balancing machine and tested to see if the balance comes within the prescribed limits. For static balance, these limits are ± 10 points, the equivalent of ⅛ oz. at a 4¼-in. radius. For dynamic balance the limits are ± 2½ points, or ⅛ oz., at 4¼-in. radius.

Service Considerations

In the matter of the service replacement of the various parts that are selected so carefully, instructions are printed in our service-shop manual, reading something like this:

> In replacing pistons and connecting-rods, be sure to weigh-up the part to be renewed and select a new one of equal weight. If only a piston is to be replaced, select from your stock one of equal weight, within ⅛ oz. The same thing applies to connecting-rod re-

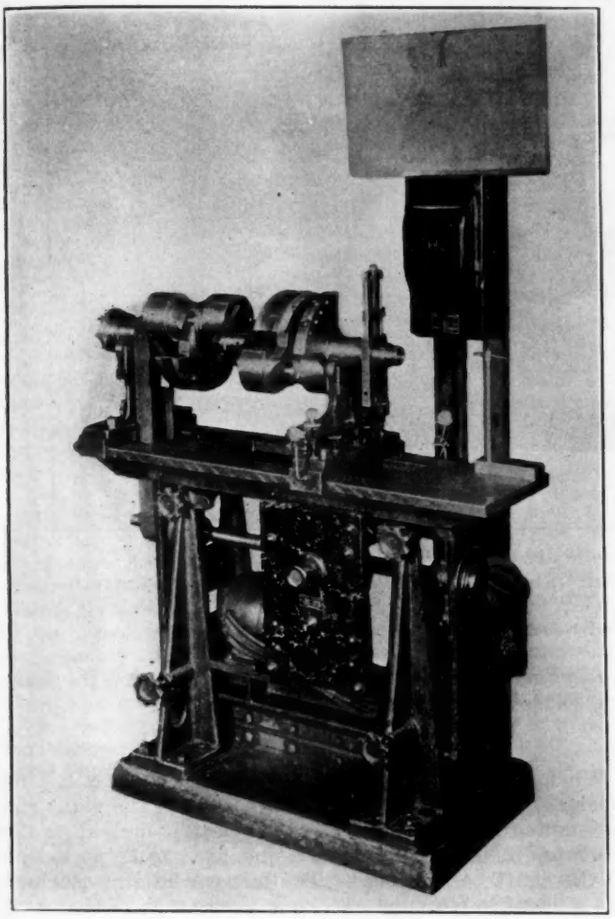

FIG. 8—FINAL BALANCING OF THE CRANKSHAFT

After the Weights Are Applied the Crankshaft Is Placed in the Balancing Machine and Balanced Statically First and Then Dynamically with the Balancing Ring Weights in Place on the Crankpin

placements. If a whole new set of pistons is required, be careful to number each piston before dismantling; this will facilitate the selection of pistons of a weight corresponding to that of the ones replaced. In case a complete new set of pistons and connecting-rod assemblies is to be installed, it is imperative that these assemblies be equal in weight, within ⅛ oz.

No difficulty is experienced by our service-station in making the selections just mentioned, as they carry a large stock of pistons. Our company's piston has been of the same design since 1917. Very few connecting-rods are ever replaced, there being nothing about them to wear except bushings that are replaceable.

FLYWHEEL BALANCING

The flywheel of the engine under consideration is a steel forging machined all over. Due to variation in the density of the metal, a certain amount of unbalance is experienced and, to obtain a smooth-running engine, it becomes necessary to balance this member also. We do not balance the flywheel and the crankshaft when they are assembled together, because, first, this assembly would be awkward to handle; second, the parts would have to be separated to place the shaft in the crankcase; third, if either the crankshaft or the flywheel were replaced, the service department would not be able to guarantee a balanced assembly without supplying both parts. We have used several different types of machine for balancing flywheels; also we have tried to put flywheels in dynamic balance. Our final determination is that the static balance gives the most uniform results.

The same type of balancing machine is used for this operation as is utilized for balancing the crankshaft, but this equipment is set for static balance only. From experience we have found that, if the flywheel is in static balance, the dynamic balance will be close enough for all practical purposes. As the flywheel is comparatively narrow, any centrifugal couple that might exist would be of small magnitude, since the axial distance between the unbalanced masses that constitute this couple is very short.

BALANCING OF OTHER UNITS

With our previous type of crankshaft, the engine had a certain amount of vibration that is inherent in its design, and it was only natural for us to lay all blame for roughness upon this fact. However, when we brought out our V-63 engine and installed it in our, then current, Model 61 chassis, a number of interesting problems presented themselves. Among these were vibrations from other units of the car, such as the clutch and the propeller-shaft assemblies. Having a perfectly balanced crankshaft and flywheel, it therefore became necessary also to balance these assemblies so as to be consistent in

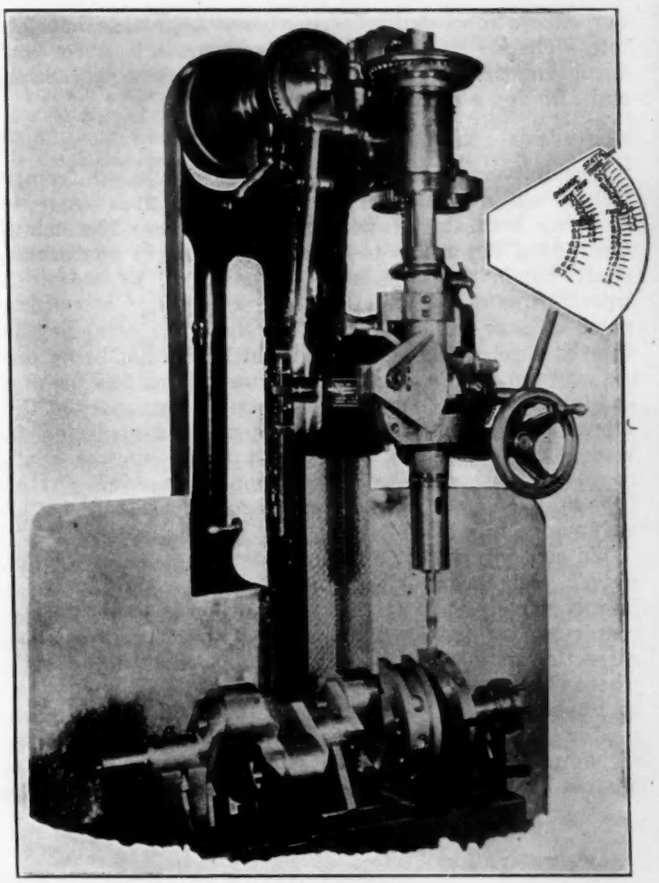

FIG. 9—EXCESS METAL IS REMOVED FROM THE COUNTERWEIGHTS BY A VERTICAL DRILLING MACHINE

This Machine, Which Has a Dial Attached to the Feed Mechanism Indicating the Exact Depth Being Drilled, Is Placed between the Two Balancing Machines. The Balancing-Machine Operator Indicates with a Height Gage on the Counterweights the Position at Which To Remove Metal and the Depth of ¾-In. Hole That Is To Be Drilled To Remove the Quantity Required To Produce a Balanced Condition. The Drilling-Machine Operator Sets the Drill for the Desired Depth, Engages the Feed and the Drill Is Stopped at the Proper Depth as Indicated by Agreement between the Number Marked on the Counterweights and the Dial Reading on the Machine

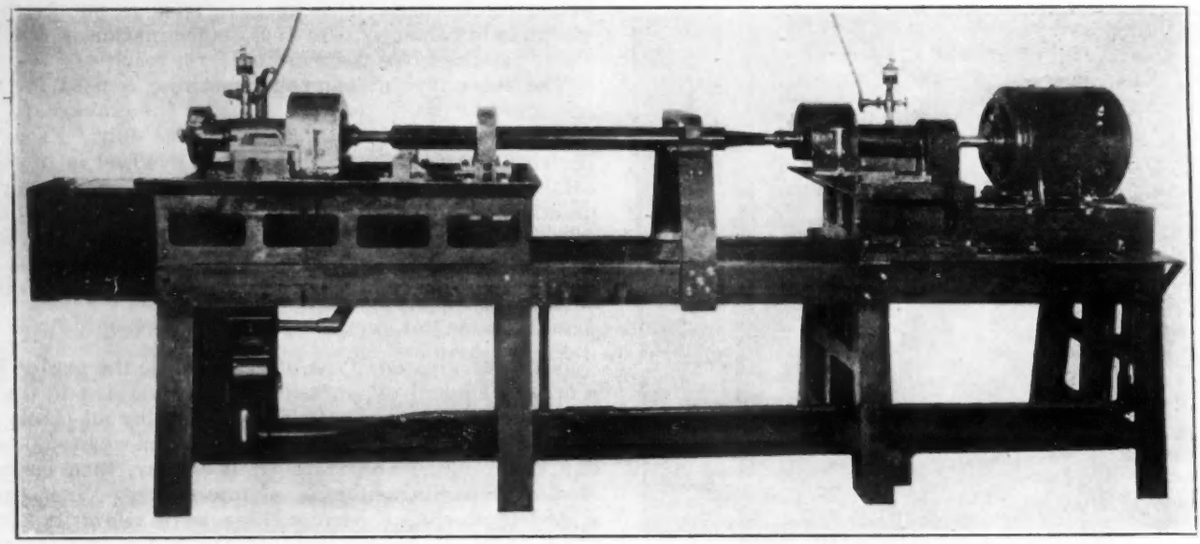

FIG. 10—MACHINE USED TO TEST UNIVERSAL-JOINT ASSEMBLIES FOR WHIP AND NOISE

At the Right End Is a 25-Hp. Adjustable-Speed Electric-Motor That Drives the Shaft Being Tested at Speeds Up to the Maximum of 3000 R.P.M. The Left End Has a Slidably Mounted Carriage That Is Used To Place the Shaft in the Angular Position It Occupies in the Car and a Brake That Applies a Load to the Shaft To Bring Out Any Defects Such as Loose Fitting Parts and Noise

our efforts toward obtaining a smooth-running automobile. The clutch drum is given a separate balance, both static and dynamic. This is done for assembly reasons and also for service interchangeability.

UNIVERSAL-JOINT ASSEMBLY

The universal-joint assemblies are purchased from a well-known manufacturer who exercises great care in securing both static and dynamic balance. The equipment used is similar to that used by us in our crankshaft balancing. We have found that, to obtain a smooth-running universal-joint assembly, something must be done besides just balancing. The balancing is done at a relatively slow speed which does not bring out the whipping tendencies that produce noticeable vibration at high car-speed. One of the contributing causes of the vibration just mentioned is no doubt the variation in wall thickness of the tubing that makes up the shaft member. Our supplier is continually checking up the tube mills on their product, endeavoring to obtain better uniformity in wall thickness.

We can only theorize as to the exact cause of "whipping." Our theory is that, in balancing a rigid body, it is only necessary to introduce an opposite couple to the couple producing the unbalance. In practice, whatever correction is needed is not made at exactly the spot where there is excess weight, this point being impossible to locate practically. This being true, it will be seen readily that two independent couples are in existence which produce forces that throw the center-line of a flexible body off from the true axis of rotation. These forces are of a magnitude great enough to flex the body, and cause the so-called whipping.

METHOD OF TESTING

When shafts are received they are placed on a testing machine, such as is shown in Fig. 10. On the right end is mounted a 25-hp. variable-speed electric-motor; on the other end a brake is provided and used to apply a load on the shaft being tested. The left end of this machine has a slidably mounted carriage, used to place the shaft in the angular position it occupies in the car. Hinged bars and guards are provided to safeguard the operator, if a shaft should get out of control for any reason whatsoever.

When universal-joint assemblies are received they are tested on this machine by speeding them up to 3000 r.p.m. and are observed for whip and noise. The brake, mentioned above, is used to apply a load that will bring out any defects such as noise and loose-fitting parts. If a noticeable whip occurs, the assembly is returned to the manufacturer. Some assemblies are corrected by giving the shaft a slight bend opposite to that produced by running. It is impossible to cure some of these assemblies of their whipping tendencies; they are, therefore, scrapped. The bending method just described sounds rather crude, but it has been proved to be the most practical remedy. If the balancing-machine builders would give some thought to the balancing of flexible rotating bodies, such as tubular propeller-shafts, perhaps they would produce an equipment that would give us a more scientific method.

Delivering Less-Than-Carload Freight by Motor Truck

By R. D. Sangster[1]

Annual Meeting Paper

PUBLIC interest in commercial activity is closely related to the cooperative functioning of the several principal kinds of transportation. As the details of the St. Louis system of using motor trucks for the terminal delivery and pick-up of less-than-carload merchandise as auxiliary to railroad transportation service have been previously described, the present discussion is devoted to outlining the practical working of this system and to demonstrating the regard in which it is held by both the shipper and the carrier.

The distinguishing feature of the St. Louis method, namely, the use of off-track freight-stations located at convenient points in the business district and a fleet of tractors and semi-trailers owned and operated by private transfer-companies, is said to have found constantly increasing favor with the public in the 16 years of its operation, so that it is now acclaimed as indispensable. As opposed to this system, a competing company using a universal freight-house and handling the freight by trap-cars is said to care for only 3 per cent of the tonnage of St. Louis proper. The opinions of various users, of investigating committees of the Interstate Commerce Commission and of a committee of the Chamber of Commerce of the United States of America regarding the relation of highways and motor transport to other transportation agencies are cited.

The effect of the store-door delivery plan is said to be the removing of railroad freight-stations from expensive land in congested parts of the terminal area to outer locations on cheaper ground, for service that would be fully as acceptable to the shipping public. That the railroads have not kept pace with the growth of traffic is indicated by the fact that in the last decade the value of manufactured products has increased over 200 per cent, whereas the carriers' investment in road and equipment has increased only 34.3 per cent; although the railroad tonnage has increased greatly, the terminal facilities as a whole have not increased, the interchange of carload and less-than-carload freight within connecting lines being the traffic most hampered. Terminal congestion is the main obstacle to good transportation and its effects are felt throughout a wide area, resulting in idle cars and a shortage of empty ones. To this might be added the fact that railroads occupying favorable locations for securing competitive traffic are loath to give them up; but if they were to take a broad view and average their advantages in one city with their disadvantages in another, a benefit common to all concerned would be realized. Experience during the war showed the advantages of cooperative operation and gave rise to the Transportation Act of 1920. Studies now in progress should be speeded up and more constructive methods of operation instituted.

Although the motor truck has been a factor for less than 10 years, its utility has been clearly demonstrated. The aggregate less-than-carload tonnage is not over 5 per cent of the total freight traffic, but the nature of the service, the revenue received and the cost of handling it bear a much larger ratio to the total earnings and expenses. One-half of this traffic is said to originate on one road and be transferred to another, and much of the freight handled in the larger cities is asserted to be connecting-line or transfer business. Taking cars out of service, the cost of motive power and the cost of rehandling add greatly to the expense. Pilferage; the loss of time of the terminal facilities, equipment, teams and crews; congestion of street traffic; the occupation of expensive real estate when less expensive sites would be equally or more suitable; large investments in non-revenue producing improvements; and the floor space now occupied for storage purposes by freight awaiting removal, are among the disadvantages that might be overcome; the advantages to be secured include the regulation of the time of delivery, the reduction of congestion during the last receiving hours and the concentration and consolidation of freight into large units, all features that would inure to the benefit of railroads adopting motor-truck service for terminal operation.

Store-door delivery and the terminal handling of freight were recommended by the Interstate Commerce Commission at the time Manhattan pier stations were glutted with war material. Although the plan did not mature because the armistice cut it short, sight should not be lost of the fact that the report of the Commission would have established in principle the systems in use in the cities of Washington and Baltimore, which had previously been in review in formal cases that had come before the Commission. The reasonableness of the service was not at issue, but the fact that the railroads were paying the cost of the service, which they wished to avoid doing. Since that time store-door delivery has been unqualifiedly favored by Special Committee 4 of the Chamber of Commerce of the United States of America.

THE use of motor trucks in the terminal delivery and pick-up of less-than-carload merchandise as auxiliary to railroad transportation service has been so widely discussed in recent years that it is difficult, if not impossible, to throw any new light on the subject. It is only because of the general interest now being manifested in the idea and because the public interest in all forms of commercial activity is so closely related to the cooperative functioning of the several principal kinds of transportation that I shall make this feeble effort to contribute anything for your consideration.

The St. Louis system was described in detail before the Society at its Cleveland Transportation Meeting in April, 1923,[2] and I can add nothing to that presentation insofar as the actual facilities and operating methods employed are concerned.

The St. Louis System

Perhaps, however, a brief statement of how that system works to relieve the St. Louis railroad terminals, and how it is regarded by both the shipper and the carrier, may be helpful in considering its adaptability to railroad city terminals generally.

The St. Louis situation embraces all the usual forms of handling merchandise in terminal cities. It is distinguished, however, by a system of off-track freight-stations located at convenient points in the business dis-

[1] Industrial commissioner, St. Louis Chamber of Commerce, St. Louis.

[2] See The Journal, May, 1923, p. 467.

tricts and a fleet of tractors and semi-trailers owned and operated by private transfer-companies, principally by the Columbia Terminals Co., through whose facilities a large part of the local and through less-than-carload tonnage is handled. The transfer-companies act as agents of the railroads. The system has developed because of the fact that the Eastern lines terminate on the eastern bank of the Mississippi River, in East St. Louis, Ill., where their main terminals are located. Established some 16 years ago, this off-track freight-station system has constantly grown in favor with the public and the rail carriers, until it is now acclaimed by both as indispensable.

In addition to these off-track facilities, a joint universal freight-house in St. Louis is operated by the Terminal Railroad Association, to and from which the freight of Eastern lines is handled in trap-cars. The relative popularity of these two systems with the shipping public, that is, of the motorized operation as conducted by the Columbia Terminals Co. on the one hand, and of the trap-car method as operated by the Terminal Railroad Association on the other hand, is evidenced by the fact that the latter agency handles only about 3 per cent of the tonnage of St. Louis proper. The trap-car has also yielded to motor equipment for the transferring of through interchange merchandise between connecting lines at the St. Louis gateway until practically none of this freight is occupying carriers' facilities in switch movement.

The attitude of the shipping public toward the off-track freight-station facility is well expressed by the statement of C. B. Lord, vice-president of the Endicott-Johnson Shoe Corporation, who, in explaining why this firm had recently chosen St. Louis over other Middle-West cities, said:

> Perhaps the strongest single factor was St. Louis' superior and unique terminal system of handling merchandise. The off-track freight-stations of the Columbia Terminals Co. represent the last word in convenient economical merchandise shipping. The investigation of the actual operating result of this system was a revelation.

This gentleman came to St. Louis with the notion that we had badly congested terminals. He was taken for an inspection of both off-track and on-track freight-houses and grew enthusiastic over the flexibility and the dispatch of the system by which freight was being passed through all the facilities; he found no congestion of less-than-carload tonnage.

After a 2 years' study of freight terminals in the St. Louis-East St. Louis district, the Engineers' Committee of the St. Louis and East St. Louis Chambers of Commerce, in its report in March, 1922, recommended against increasing the capacity of on-track freight-stations, advocating that

> The present system of universal off-track freight-stations of transfer companies should be extended and enlarged. Additional off-track freight-stations should be built at locations where there is sufficient freight to justify them.

In support of this recommendation the Committee made the following finding:

> In the Committee's opinion the principle of off-track universal freight-stations is correct, and the facilities should be developed in St. Louis. The system presents the necessary element of flexibility which lends itself to a city whose street traffic is congested and whose commercial industrial districts are widely distributed. The system promotes the short haul of less-than-carload freight and the accumulation of such tonnage into lots that can be moved with the greatest economy and dispatch to and from the rail haul. In developing the system in St. Louis, the rail carriers should assume close supervision, so as to render it, without physical ownership, practically a carrier service, thus becoming directly responsible to the shipper and the receiver of freight for the result of operating the system in the interest of efficient service to the public and economy to the carrier. Such stations should be located in sections of the city where tonnage to be handled may justify and include, so far as practicable, outer districts remote from main freight-stations.
>
> All such locations must be controlled primarily by the tonnage available and thus by the possible extent of the use of such facilities when provided, without encroaching upon the tonnage and operations of other stations.

Adaptability of the St. Louis System to Store-Door Delivery

The St. Louis facilities and methods are ideal as a groundwork on which to establish store-door delivery. The system is closley geared to the actual operations of the carrier and the consignee. It is well established, has all the machinery for performing, and does perform, not only the manual labor but all the clerical accounting incident to the handling of the freight between the freight-house and the consignee's premises, in fact relieving the railroad company from all terminal services. Therefore, in St. Louis an opportunity exists for a practical demonstration of store-door delivery.

The St. Louis system has been reviewed by the Interstate Commerce Commission in a formal proceeding decided June 28, 1915, in the matter of terminal allowances and rates at St. Louis, Mo., and East St. Louis, Ill. After discussing the allegations as to the discriminatory effect of the system the Commission found that

> The Eastern and other lines have made use of the services of the transfer companies instead of using the facilities of the St. Louis Terminal Association between East St. Louis, Ill., and St. Louis, because it enabled them to handle their inbound and outbound traffic with less delay and with greater convenience.
>
> Although the Western lines have rail depots of their own in St. Louis, many, if not all, of them have made similar arrangements with the transfer companies, under which the off-track stations of the Eastern lines have become the freight stations also of the Western lines.

and held that

> The operation of off-track freight-stations by certain transfer companies in St. Louis as public freight-stations of the carriers is found not to be unlawful or to result in discriminations that are undue.

Since this case was decided, the powers of the Inter state Commerce Commission have been extensively increased by the Transportation Act of 1920 over the service, as well as the charges and the practices, of interstate common-carriers, and new provisions in the law relate directly to the use and the operation of terminal facilities. While many of these new provisions have not been reviewed by the courts, it is hardly to be denied that Congress thereby implicitly directed the Commission to order the unification of terminal facilities and, necessarily, the pooling of traffic for terminal handling where the public interest would be served. The Commission, therefore, is now in a position not only to approve but to require the establishment of store-door delivery, whereas the law was not so clear when the Baltimore and

the City of Washington cases were decided some 12 years ago purely on allegations of discrimination.

Much thought is now being given to the public necessity for coordinating the various kinds of transportation upon which the commerce of the Country depends so vitally. The Chamber of Commerce of the United States of America has recently held a national transportation conference for the consideration of reports made by a number of special committees on various phases of transportation agencies, policies of regulation, and the like.

The matters covered by the Chamber of Commerce program present transportation problems of nation-wide interest; the conclusions and recommendations of the various committees recognize the interdependent relations of our principal modes of domestic transportation.

Relation of Highways and Motor Transport to Other Transportation Agencies

This subject was treated at length by one of these committees, whose personnel embraced authorities of unquestioned ability in the transportation world. The committee made certain definite findings and recommendations, which are given below.

> The congestion of transportation today centers around the terminals of our great cities, and it is at these terminals that the railroads find the greatest difficulty in keeping pace with the public need. With hardly an exception the main tracks of our railroads have sufficient capacity for the movement of more freight than can be offered to them. Still, in spite of this fact, the railroads are constantly faced with a demand for more and better terminal facilities in the face of prohibitive real-estate values and other stupendous obstacles to expansion. Here lies the greatest opportunity for the motor truck. By the use of motor transport the facilities of the terminals can be expanded so as greatly to increase their capacity.
>
> Store-door delivery by motor truck, which would relieve congestion in these terminal areas and greatly increase the capacity of the freight stations, is undoubtedly the greatest contribution that can be made to the solution of the terminal problem.

In discussing how the motor truck can serve in relieving terminal congestion and in avoiding needless duplication of freight stations and team tracks in city terminals, the committee says:

> The general demand for more and better rail transportation is insistent, and the railroads are confronted by a serious dilemma. They must either add to their present terminal facilities or find a way to pass more freight through them. Enlargement or multiplication of terminal stations and team tracks in important terminal areas is practically impossible because of prohibitive cost, objection of municipalities to the expansion of railroad holdings in congested areas and, furthermore, the additional traffic congestion that would result from greater centralization of cartage operations in such areas.

And again,

> A well-organized system of store-door delivery by motor truck would be perhaps the greatest contribution to the solution of the terminal problem.

The committee would include in store-door delivery not only less-than-carload freight, but also team-track carload traffic. With regard to the effect on street congestion, the committee says:

> The substitution of an organized trucking system for the miscellaneous haphazard service now employed for station work would greatly increase the load efficiency of vehicles, thus reducing the number on the streets. It would speed up street traffic and reduce the danger to pedestrians.

Relocation of Freight-Stations

It is held that the effect of the store-door delivery plan on the location of railroad freight-stations would ultimately be to remove them from expensive land in congested parts of the terminal area to outer locations on cheaper ground, for service that would be fully as acceptable to the shipping public.

The committee reproduces excerpts from a report by the leading authority on railroad cartage in Great Britain, J. Pepper, general manager, Northern Counties Committee, London, Midland & Scottish Railway Co., who makes the following comments on the subject of store-door delivery:

> I think you would be safe if you fixed your station to station conveyance rates [the English equivalent for freight rates] and based your cartage rates on mileage. If you do that there should be no incentive for the man who wants to cart his merchandise himself to pick and choose. In fixing your cartage rates you would have to be careful to make the charge for the distances around your stations per ton per mile as low as you consistently can, because obviously the lower it is the less likelihood there would be of any one wanting to do the work himself.
>
> It may perhaps help you in your campaign if I tell you that from my very intimate knowledge of most of the large goods stations in England I am entirely satisfied that unless the railway companies had many years ago undertaken cartage work themselves their existing depots would have been many times larger than they are today and we here would have been up against precisely the same problem as the one facing you in America.
>
> If you are ever able to accomplish what you have set out to do I am satisfied that the congestion at your freight terminals will completely disappear and you will probably find in the end that your terminals will be larger than you require.
>
> You will be more likely to succeed if you start at one place, and I would suggest to you that if you can find a self-contained terminal that is not too big but that is very congested you will be able to demonstrate clearly the effect of your philosophy.

With regard to cartage charges for store-door delivery, the committee suggests that

> The charges for organized cartage should be borne by the traders as they are now, but should be less than the present cost of unorganized cartage and still should be sufficient to produce fair profits for the cartage organization and should be covered by separate tariff rates. Such rates should be uniform within certain zones in the terminal area.

The foregoing expressions are quoted as reflecting some of the best transportation thought of the Country, after years of experience with and painstaking study of conditions in this Country and abroad.

In considering store-door delivery, it cannot be too often repeated that the capacity of our railroads, as a whole, has not kept pace with the growth of traffic, and that it is primarily due to the congestion of railroad terminals that freight transportation is slow and car supply is short periodically.

The Growth of Industry Outstrips Railroad Capacity

Tables 1 and 2 are taken from Part 3 of the Joint Commission of Agricultural Inquiry's Report to the 67th Congress.

TABLE 1—TOTAL OUTPUT OF MANUFACTURERS AND CAPITAL EMPLOYED

Year	Total Output of Manufacturers	Manufacturing Capital Employed
1910	$20,672,000,000	$18,428,000,000
1920	65,500,000,000	50,000,000,000

The manufactured output increased in the decade 200 per cent, whereas the carriers' investment in the road and the equipment increased 34.3 per cent.

There was, of course, an increase in the tonnage of field, forest and mine products as a whole. The loss in lumber tonnage was made up by the increased production of petroleum. The tonnage carried by the railroads in 10-year periods from 1883 to 1923, inclusive, is given in Table 3.

The pressure of this tonnage is greatest upon the terminals, particularly at the principal traffic gateways and at the ports. No corresponding increase in the terminal facilities as a whole has been made, and the interchange of carload and less-than-carload freight between connecting lines in all the larger cities is the traffic movement most hampered.

TABLE 2—PROPERTY INVESTMENT OF THE CLASS 1 RAILROADS IN ROAD AND EQUIPMENT

Fiscal Year	Property Investment
1911	$14,246,167,475
1920	$19,134,000,000

Methods of Operating the Terminals Are the Source of the Railroads' Incapacity

To one who has spent some 25 years in freight transportation and traffic service, alternately on the railroads' and the shippers' sides of the question, my observation is that the main obstacles to good transportation arise from terminal congestion, caused frequently by the detached methods of operating terminals and of handling freight in terminals by the many individual railroads and agencies. The bad effects of terminal congestion are by no means confined to the city, but spread throughout a wide area, slowing down large volumes of through traffic, domestic and export. As individual cases of congestion multiply, the disastrous effects increase. The railroad plant is progressively oversaturated with freight traffic, particularly during every business revival, and during such periods the stress is most acute at the larger terminal cities. Blockaded terminals mean idle cars under load and, in consequence, a shortage of empty cars, and these elements react upon each other in a vicious cycle, as the shipping public and the carriers know to their sorrow from the bitter experiences of the last 5 or 6 years.

But without cooperative and affirmative action by the railroads it will be difficult, if not impossible, to establish reforms in terminal operations. United action by the terminal lines in any one city is fraught with obstacles, a particularly stubborn one being the case where the terminals of one or more of a number of roads occupy advantageous inner locations that are selfishly regarded as a big factor in attracting competitive traffic. Until the railroads in such circumstances take a broad view and average their individual advantages at one locality with their relative disadvantages at other localities we shall get nowhere on a solution of the terminal problems.

TABLE 3—RAILROAD TONNAGE FROM 1883 TO 1923

Year	Tons Carried One Mile	Increase Over 1883, Per Cent
1883	44,064,923,445	...
1893	93,588,111,833	112
1903	173,221,278,993	293
1913	297,722,528,693	576
1923[a]	430,000,000,000	876

[a] December estimated.

Frequently during the late war congestion at North Atlantic seaports was backed up, in effect, all the way to the Rocky Mountains, and the consequent idleness of freight cars, tied up under load, resulted in repeated general car shortages. The net result was that at intervals civil commerce and trade, depending on transportation, largely ceased. It was in fact, out of the transportation experience of the war that the movement sprang to correlate the various principal agencies of transportation, which gave rise to the Transportation Act of 1920, removing the ban of the Sherman Law against railroad consolidations in the public interest, comprehending other high principles of governmental regulation, recognizing the universal character of transportation and the interdependent relation of railroads and waterways, all of which, in turn, being reflected in the great amount of study now being given to the general subject of transportation. These studies should be speeded up, and constructive methods, even if revolutionary, should be put into execution as rapidly as possible, for the self-preservation of American commerce and for the retention of American principles of private ownership and operation of common carriers that are threatened by the progressive congestion of the transportation plant as a whole, particularly at all large traffic centers, in comparison with the increased production and industrial output of the nation.

The Motor Truck a Big Factor in Terminal Operations

The production of motor vehicles in the years 1904, 1914 and 1922 is given in Table 4.

TABLE 4—MOTOR-VEHICLE PRODUCTION STATISTICS

Year	Passenger Cars	Motor Trucks
1904	21,282	411
1914	543,679	25,375
1922	2,406,396	252,668

During the calendar year 1923 over 4,000,000 passenger cars and motor trucks were built.

The motor truck has been a factor of transportation for less than 10 years, but its utility in the short haul of freight has been clearly demonstrated. Its general use, in conjunction with rail transportation at the origin and the destination ends of the haul, would serve to relieve the pressure on terminal facilities, automatically increasing their capacity more quickly and more cheaply than any other one thing that could be done. What is needed is to demonstrate more completely the organized efficiency of motorized equipment in this service.

It has been suggested that such a demonstration, contemplating the store-door delivery of merchandise at selected cities by the railroads, or by organized trucking companies acting as their agents, might involve embarrassing discrimination. But terminal facilities being of local character, the methods of terminal operation should properly be such as to respond to local conditions without involving locality discrimination of an undue or illegal sort.

The railroads, in their own interest, should be moved to adopt improved methods of handling merchandise at city terminals because of certain very definite factors

now existing. The aggregate less-than-carload tonnage is not over 5 per cent of the total freight traffic, although the nature of the service, the revenue received from the traffic and the cost of handling it bear a much larger ratio to the total earnings and expenses. *The Railway Age* is authority for the statement that approximately one-half of this freight originates at a point on one road and moves to a point on another. Such freight must be transferred by and at the expense of the originating road to the receiving line at a junction-point, and is frequently interchanged several times before the shipment reaches its final destination.

A very large proportion of the total less-than-carload freight handled in the larger cities comprises connecting line or transfer business. This interchange between connecting lines is now performed, either by moving the freight from one freight house to another by trap-car or by trucking it directly across the city. As indicative of the magnitude of the less-than-carload freight-interchange movement through the larger cities, an exhaustive investigation of the traffic handled in Chicago a few years ago showed that over 6,500,000 tons of less-than-carload freight passed through the forwarding freight-houses in that city annually, of which about 60 per cent, or approximately 4,000,000 tons, was received in interchange from other roads. Approximately one-half that interchange, or about 2,000,000 tons, was trucked along the streets from one freight house to another, and an equivalent amount, or approximately 6500 tons daily, was moved by trap-cars.

The cost of trap-car service to the carriers on account of the consequent occupancy of rolling stock and terminal tracks, the use of motive power and the incidental re-handling of such freight by freight-house crews, if computed, would be found to be a considerable expense of operation. To the extent that cars are used in such service, they are not available for the more profitable carload long-haul traffic. The cost of claims on account of the pilferage from trap-cars handled in and lying around terminals is, in itself, a large item that would be greatly reduced by better policing through an organized trucking system.

The element of time is another factor reflected in the cost of terminal operation, that is, the required extent of the use of the terminal facilities, equipment and working crews, which would be greatly reduced by motor-truck service. Team and motor-truck detention around less-than-carload freight terminals and the incidental delay in receipting and forwarding merchandise are costly to the city trader, whether he does his own carting or hires it done, and to the carrier as well.

Street Traffic Congestion Reduced

The contribution to street-traffic congestion in cities by the present system that confines railroad freight-houses within and adjacent to the business section, and the consequently greater number of small-unit carloads operated by traders or their agents to and from the freight houses of the carriers, are a great community loss that should and must be retrieved in the public interest. The excessive cost of railroad terminal service given to less-than-carload merchandise is the reflection of a number of factors.

The expensive real estate now occupied by facilities at inner locations whose capacity cannot be expanded except by undue financial investment is one of the more prominent sources of cost to the railroad, although it is not usually figured in the cost per ton of station expense against less-than-carload freight. W. H. Lyford, vice-president of the Chicago & Eastern Illinois Railway Co., has shown that a difference of 2 miles between the locations of two stations in a large city may make a difference of 300 per cent in the interest charges on the real estate occupied by the stations; that in Chicago the interest charge alone on real estate at 12th Street is more than $2.30 per ton of freight handled through a station at that location; that if the station were removed to 33rd Street this interest charge would be reduced to about 80 cents per ton, and he finds that the amount of interest thus saved would pay the cost of well-organized cartage between the 33rd Street station and the traders' premises, the present cartage charges being eliminated. The continued large and increasing investment of capital in non-revenue-producing improvements, such as freight houses and public-delivery tracks in the downtown sections of cities, cannot be justified in the face of the economies that store-door delivery and pick-up of the freight using such facilities promise.

Much of the floor-space of inbound freight-houses is occupied by freight in storage awaiting the pleasure of the consignee as to its removal, and the average time such freight is held by the carrier is 3 days per shipment. When the storage-capacity of inbound houses is reached, cars under load with merchandise are held in outer yards at the carriers' expense awaiting space. The piecemeal and leisurely delivery of inbound merchandise through a multitude of different vehicles, rather than immediate delivery through an organized system of cartage, results in a great cost that the public at large must assume and in needless delay.

The congestion of outbound freight-houses at certain hours of practically every business day, because of the custom of shippers of delivering freight to the carrier in the last receiving hours, tends to and does produce congestion and inefficiency among crews at all the large terminals and adds to the shippers' and carriers' costs. That condition can be and has been largely cured at St. Louis, by a system of off-track freight-depots into which the merchandise of all shippers is concentrated and consolidated into large units up to 10 tons for delivery to the carrier. Such a method minimizes the moving of the same unit from depot to depot.

The individual carrier's freight-house capacity for inbound and outbound freight is frequently more than ample for the normal demand, in anticipation of the peak load that is thrown on it periodically, and results in wasted floor-space during a large part of the time, which is costly. The foregoing points out the possible economies and benefits that would inure directly to the railroads if they were to employ an organized motor-truck service at the larger terminals.

The benefits would be mutual to the carrier and to the trader, through a better coordination of railroad and motor-truck transportation in the terminal operations.

The Motor Truck a Transportation Instrument

The motor truck has arrived as a transportation instrument and has been generally adopted by other industries. It is not less adaptable for complementary service in the railroad industry, and its use could be likewise adopted for practical service by the carriers. The day has passed, because of the ascendency of the motor truck, when the railroads can leave their less-than-carload freight to shift for itself at both ends of the rail haul. The service of transportation is of value to the trader from the time the shipper's invoice is made out until the goods have been delivered to the customer's premises.

The railroad freight-houses should be converted from storage receptacles into facilities for clearing, in an unbroken stream, less-than-carload merchandise at the origin and at the destination. The road to that result lies in the railroads' taking hold of and revising the methods of discharging and receiving less-than-carload freight through these facilities, by consolidating the service into fewer hands and larger tonnage units. The proper type of facility and the method of operation are questions to be settled by the broader interests of the whole community and all the carriers serving it, patterned to meet local conditions in each instance.

The advantageous location occupied by the freight houses of one or more railroads in a city should not act as a bar to changing a system that is inimical to improved and more economical service, if it is in the public interest to do so. Unless and until the railroads recognize the futility of holding to these competitive selfiish advantages and are willing to pool their terminal operations in a system that promises relief, their terminal problems will grow apace and the public interest will continue to suffer.

Consolidation of Tonnage

The fundamental fact, recognized by all interests, is that less-than-carload freight tonnage should be consolidated, for the cartage haul, into the largest possible units consistent with dispatch and efficiency. This consolidation of tonnage cannot be made unless the railroads take the initiative and assume greater responsibility for and closer supervision over the service between their terminals and the traders' premises and cooperate to curry the favor of the shipper and of the consignee.

As to including for store-door delivery the carload freight from public team-tracks, this is a matter that should be dealt with on its merits in each locality; and this suggestion relates, as well, to any necessary difference of treatment, even in the same terminal area; that is, store-door delivery might be made applicable from certain team-tracks and not from others, depending on the location and the congested condition of the tracks, their capacity and the practicability of expanding such capacity. It is, I believe, literally true to say that store-door delivery in this Country has been avoided by the railroads because, primarily, of the fear that sooner or later they might be required to absorb its cost, in whole or part, out of their line-haul revenue. The service has a value to the trader and should be considered on the theory that he will be willing to bear the fair cost of it if the charge is properly adjusted and the quality of service is improved. He, however, has the right to expect and to receive the full benefit of the economies that an organized operation should yield and to participate in them jointly with the carriers, through the level of the cartage charges he pays. Many benefits to the railroads are patent, and any trouble or expense that they may incur will be a very profitable investment yielding direct returns; on the other hand, the present system has elements of apparent advantage to individual traders here and there, the contemplative surrender of which should be met by proper compensation. Store-door delivery should be introduced gradually and, preferably, should be demonstrated by a thorough try-out in such selected cities as offer the essential element of cooperation between all interests.

In the organization of trucking companies as carriers' agents, under contracts fully protecting the public interest, due consideration should, of course, be given to the larger existing cartage companies, to their facilities and investments in property devoted to the cartage business, and to the fact that they, as well as many traders, may be handling a large local cartage business between points in the city not related to railroad carriage. Some traders will doubtless desire to continue their own handling of both inbound and outbound less-than-carload freight, while others may desire to continue handling outbound freight only, for the purpose, in either or both cases, of employing their present facilities that are largely devoted to cartage operations detached from road haul traffic.

Advantages of Off-Track Freight-Stations

A system of universal off-track freight-stations for collecting outbound less-than-carload freight and for consolidating it into large-unit loads is highly attractive, offering, as it does, the shortest haul for the shipper to perform, one dump of his freight regardless of destination or route, reduced delay at the freight houses, the latest hour for receiving freight for forwarding on the day of shipment and economies in the costs of handling by the carrier. The charge for the service to the average trader who performs his own cartage, as well as to the trader who hires his cartage, should not increase, but should lower the present expense of his whole cartage service. The amount of the charge will necessarily be influenced in various cities by topographical and physical conditions, the volume of traffic and always by the length of haul. The system should be flexible enough to accommodate deliveries and pick-ups to the hours of the day most convenient for the trader.

Organized store-door delivery should be subject to regulation by the Interstate Commerce Commission, particularly the service charges, which should be on a uniform basis in different cities under similar conditions. It is assumed that this service would be confined to the larger cities where the terminals are subject to the heaviest pressure and where the value of the service would forcefully appeal to the trader; it is inconceivable that there should be a necessity or a demand for the service at every distributing point in the Country.

It should be made optional so that the consignee may have a choice and may not be left to depend solely upon the carrier service. Obviously, conditions with many traders are such as to require optional service, particularly at the outset. Some of these include limited floor-space, elevator facilities serving upper-floor locations, narrow and restricted street or alley approaches that are too small to accommodate large trucks and motorized units and inability to receive freight on its arrival that is moving under consignment and seeking a market.

The carrier service should be made so attractive, however, in its operation that it will draw the bulk of tonnage from the beginning, and certainly the business of the larger traders whose shipments are continuous and of uniform volume.

The Harlan Plan for Manhattan Island

That store-door delivery and the terminal handling of freight are local matters is demonstrated by the report and recommendations of former Commissioner James S. Harlan of the Interstate Commerce Commission to the Director General of Railroads, with regard to the merchandise situation on Manhattan Island. The report was dated March 30, 1918, at a time when war tonnage had blocked all the traffic facilities in the New York harbor district and an emergency existed. In that report the

commissioner recognized and publicly declared that the disposition of less-than-carload merchandise by the store-door delivery system promised greater relief for the glutted condition of Manhattan pier stations and the confusion of cartage operations upon Manhattan Island than did anything that could be done. The situation not only stagnated the largest American port, but its influence was felt throughout a large section of the Country and involved an enormous volume of traffic; and to it it was proposed to apply an effective, if heroic, sort of treatment.

Although the plan did not mature because the armistice cut it short, the commissioner's recommendations must be considered as reflecting the judgment of a high member of the most powerful transportation regulating tribunal in the world, the Interstate Commerce Commission. And sight should not be lost of the fact that his report would have established in principle the very system of handling less-than-carload freight that had been under review by the Commission in formal cases in other communities previously; that is, in the City of Washington, and in Baltimore, wherein the Commission, by formal order, declined to require the continuing of store-door delivery.

In these cases the issue of store-door delivery was presented primarily on the grounds of discrimination under the Act To Regulate Commerce, and they were heard and disposed of under normal transportation conditions. The reasonableness, per se, of store-door delivery was not primarily at issue in the cases cited. In all those cases, however, the railroads were paying the cost of the service and for that reason wanted to get away from store-door delivery where it had been in existence; likewise, they wanted to avoid spreading the same practice by any new similar installations.

Store-door delivery can be established on an important scale only by the initiative and active support of the railroads, and it would seem that in their own interest the time has come for them to make a move in the direction of store-door delivery and pick-up not only of less-than-carload freight but also of carload traffic using public team-tracks in the larger cities. It is doubtful whether, at the time of that investigation, the Interstate Commerce Commission had the power to establish store-door delivery by formal order, but their present powers over terminal operations are apparently unlimited. Commissioner Harlan was dealing informally with the New York City situation in recommending the execution of the practically unlimited war-time power of the Director General of Railroads.

The idea must have made some progress in the intervening period with the railroads, however, according to expressions of Special Committee IV of the Chamber of Commerce of the United States of America on the Relation of Highways and Motor Transport to Other Transportation Agencies. The personnel of that committee embraces some very prominent railroad men whose knowledge and authority are unquestioned in transportation matters; it likewise embraces talent of undisputed authority representing the industrial and shipping interests of the Country. The committee's recommendations are not qualified in favoring the establishment of store-door delivery.

Taking Commissioner Harlan's views in the war emergency as to what should be done on Manhattan Island, the deliberate recommendations of the peace-time special committee of the Chamber of Commerce of the United States of America on the subject and the years of experience with the system in the cities of Baltimore and Washington, it appears clear that the principle of store-door delivery is sound and practicable and is now worthy of a trial for the relief of city terminals and as a preventative of terminal congestion. The burden of proof, therefore, should be upon the railroads and all other related factors that would longer withhold from the general public so efficacious a measure.

AUTOMOBILE TRAFFIC REGULATION

LAST year for the first time in the history of the automobile industry the total production of cars and trucks exceeded 4,000,000, a gain of 50 per cent as compared with 1922, the previous record year. It took perhaps 5,000,000,000 gal. of gasoline to run them. These cars and trucks represented a wholesale value of $2,500,000,000. Parts, tires and accessories totaled $2,000,000,000 more. We have been increasing the units of transportation faster than the streets and highways on which they operate.

In 1921, the latest year for which complete statistics are available, somewhat in excess of 1,250,000 persons died in the United States from all causes; 74,000 of these met death by accident. While 12,500 motor-car fatalities comprise a most alarming total, yet this number is less than the deaths from firearms, which amounted, in the same period, to 14,450. Twelve thousand five hundred deaths in 1921 meant 1 for every 837 cars in use; 15,750 deaths in 1923 meant 1 to every 921 cars in use, an appreciable reduction. To my mind it is a fair question if the driver is actually responsible for more than half the cases. A policy that records only the results, without attempting to ascertain the causes, is futile.

Because of superior methods applied by Massachusetts, fatalities in that State were reduced from 532 in 1919 to 500 to 1922, whereas in New York in the same period they grew from 1361 to 1725. Many deaths are preventable under proper regulation. Everybody concedes that one of the greatest needs is standardization of regulations. It is also admitted that this is most difficult of accomplishment. This need of uniformity is two-fold, as follows:

(1) Signals to be made by the drivers themselves
(2) Signs and signals to direct traffic

I believe that all the intricate attempts at driver signal-systems are fallacious. I do not believe that any set of hand signals can be perfected for general use which will infallibly indicate the driver's purpose to stop, back up or turn to the right or the left. In my judgment, there is just one thing to do and that is to thrust out the left hand as a sign of warning. This will act as a signal to slow-up everything behind until the driver's intentions have been ascertained. Wherever standards are generally accepted these should be followed.

The statistics of Massachusetts and Maryland indicate speeding as a major cause of automobile accidents, 158 out of 522 deaths being reported as so caused. Intoxication was the cause in 10 per cent. Judge Bartlett, of Detroit, has expressed the opinion that only jail sentences stop the reckless driver. The automobile industry pledges its full support to every judge who imposes jail sentences for proved offenses, no matter how severe may be the penalty. We believe also in the suspension or the revocation of the license as a penalty. We propose that, when after due process of law a driver is proved responsible for a serious accident or death, in addition to all penalties now imposed, he should forfeit possession of his automobile for a period to be determined according to the seriousness of offense. We believe that it is not enough to take the license. Take away the car, too.—George M. Graham, chairman of the Traffic Planning and Safety Committee of National Automobile Chamber of Commerce.

Chassis Lubrication

By Fred H. Gleason[1]

Detroit Section and New England Section Paper *Illustrated with* Drawings

MEANS generally employed for chassis lubrication are classified into six groups by the author, who says that fairly efficient lubrication can be accomplished with any of them if they are attended to; but, because chassis lubrication is a dirty and lengthy job when such means are used, complete neglect by the car operator results eventually.

Referring to the respective characteristics of grease and of oil, those of oil are summarized and preferred. A centralized oil-lubrication system is then described in detail and illustrated, it being composed of a central oil-reservoir and pump, a main-supply line that runs from the pump to one or more control headers and delivery tubes that extend directly to the points or the bearings lubricated. Its features of advantage are discussed under the headings of operation, accuracy of oil control, details of construction and installation, flexible tube construction, lubrication of special parts, flushing and wear. Ten general conclusions are specified.

IN connection with the ownership and operation of the modern automobile, the meanest and most disagreeable job is that of lubricating the chassis; in fact, considering the means of lubrication generally supplied by the car builder, the inveterate laziness of the average owner results in the continued neglect of all chassis bearings.

While engine bearings will give prompt notice of the lack of proper lubrication, the general construction of chassis bearings will permit their operation with little or no lubrication for long periods of time, without actual failure of the bearings. Continued neglect of these bearings eventually will result in rusted and worn chassis parts, annoying squeaks and rattles, stiffness in the steering and harshness in the riding qualities of the vehicle.

The various means generally employed for chassis lubrication can be classified roughly as being

(1) Grease-cups, plain and combined with springe feed
(2) Oil-cups, plain and combined with wick feed
(3) Oil-cups, feed-controlled by the motion or vibration of the part lubricated
(4) A reservoir having wick feed
(5) An individual reservoir having pump feed, hand-controlled
(6) Grease and oil-guns with nipples having manually maintained or locking detachable connections

Fairly efficient lubrication can be accomplished with any of the above-named devices, provided they are regularly attended to; however, due to the fact that it is a dirty job, which requires considerable time, to lubricate a chassis properly with any of these means, the car operator continues to defer the lubrication of the chassis to a more convenient time and, finally, to neglect it until the chassis bearings are clogged partially or completely with a mixture of worn-out lubricant, road dust, rust and particles of metal that have been rubbed from the surfaces of the bearings.

The respective merits of grease and oil as mediums for chassis lubrication have been ably discussed in papers by many previous authors. In this connection the following summary[2] by Cornelius T. Myers states the advantages of oil very clearly.

> Oil as a lubricant has advantages over grease, but its proper application to chassis bearings has required more painstaking effort in design than has usually been given to it. This has previously mitigated against its use, especially on passenger cars, but the advantages that follow are appealing more and more to designers and to users.
>
> (1) Oil will sustain as heavy a bearing load as grease, and with less friction
> (2) Oil fed to one properly located point in a bearing will quickly spread over the entire surface
> (3) Oil will flow through a very small hole, and it can be conducted a considerable distance by capillary attraction and surface tension
> (4) Oil will carry much less dirt than grease; it can be filtered, and it is not nearly so much exposed to dirt when in bulk or when being applied
> (5) Oil contains no inert matter to clog holes and channels
> (6) The oil used in the engine can be used in the chassis oilers, eliminating the necessity for carrying two kinds of lubricant
> (7) Oil is much more easy to apply automatically than grease
> (8) A flow of clean oil tends to clear a bearing of any dirt that it may contain, and a bearing arranged for oil lubrication can be flushed and cleaned with gasoline or kerosene
> (9) When oil is used on spring-bolts the seepage works down into the spring leaves and keeps them from rusting, then stiffening and sometimes breaking

As compared with grease, the use of oil greatly facilitates the work; not only is oil cleaner, but it lends itself to expeditious handling and possesses the valuable quality of creeping or penetrating, which aids materially in getting it between the surfaces in need of lubrication. The great difficulty with grease is that, when a bearing is subjected to shock, the grease does not "cushion" like oil; the oil will resist, slide away gradually and then dart back to the point from which it has been squeezed.

The ideal motor-vehicle should be designed with the convenience of the owner and operator in mind rather than that of the factory. The major part of the labor necessary to maintain an automobile in good running condition is that required to lubricate the many chassis bearings. I believe that the incorporation in the chassis of a simple dependable device making possible the efficient lubrication of all chassis bearings and eliminating the time, the dirt and the labor involved in the operation would be more appreciated by the owner and the driver than any other improvement that can be made over

[1] M.S.A.E.—Experimental engineer of chassis lubrication, Bowen Products Corporation, Auburn, N. Y.

[2] See *Motor Age*, Dec. 8, 1921, p. 18.

present construction. It would also be a powerful sales-argument in the hands of the retail salesman.

Centralized Oil-Lubrication System

The corporation with which I am connected has developed an efficient inexpensive centralized lubrication-system that uses oil for lubricating the chassis bearings of an automobile. This system comprises a central oil-reservoir and pump with a main-supply line leading from the pump to one or more control-headers from which delivery tubes extend directly to the points or the bearings lubricated.

Fig. 1 shows the main units of the system and the method of control. The reservoir is of cast iron and has a capacity of 50 cu. in., or approximately 1 qt.; it is provided with a cylinder at the bottom. A plunger with a foot-button at its upper end operates in this cylinder. The plunger is maintained normally at its top position by a spring and a stop-collar; when in this position, the milled portion at the lower end acts as a guide and also provides passage for the oil from the reservoir to the cylinder. The top of the reservoir is closed by a cover having a filler-plug and is provided with a guide for the plunger. The guide has a leather washer, held in place by a steel shell that acts as a wiper for the plunger. The lower end of the cylinder is closed by a combined screen and drain-plug, from which a passage extends upward parallel with the cylinder and terminates in a double 5/16-in. tubing connection. The unit is secured to the chassis frame by two ¼-in. S.A.E. standard bolts and one ⅜-in. cap-screw.

The method of attaching the unit to the chassis frame does not weaken the frame materially because only two small 17/64-in. holes, drilled away from the edge and close to the side member, are required in the upper compression-member of the frame. The accessible drain-plug and the screen, being at the lowest point of the unit, permit draining the reservoir and the pump-cylinder completely and cleaning the screen. The oil passes through the fine-mesh screen in the plug before it can enter the tubing lines. The location of the tubing connections at the base of the reservoir permit a neat installation, with the tubing and the connections inside of and protected by the frame.

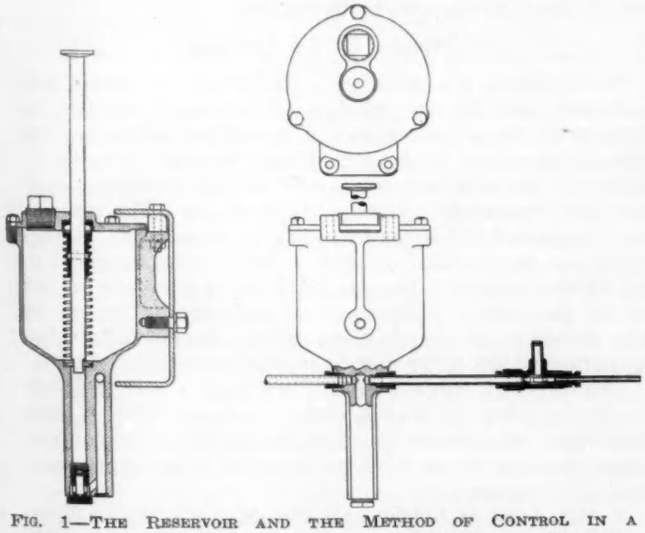

Fig. 1—The Reservoir and the Method of Control in a Centralized Lubrication System for an Automobile Chassis

The 1-Qt. Cast-Iron Reservoir Has a Cylinder at the Bottom in Which a Plunger with a Foot Button at the Upper End Operates. Normally the Plunger Is Kept in the Position Shown by a Spring and a Stop Collar and When in This Position the Milled Portion at the Lower End Acts as a Guide and Also Provides a Passage for the Oil from the Reservoir to the Cylinder. The Lower End of the Cylinder Is Closed by a Combined Screen and Drain Plug That Permits Complete Drainage of the Reservoir and the Pump Cylinder and Cleaning of the Screen. The Oil Passes through the Fine-Mesh Screen before It Can Enter the Lines of Tubing Leading to the Bearings

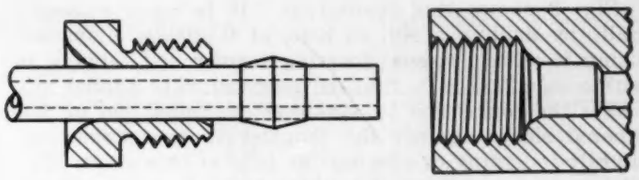

Fig. 2—Tubing Connection

This Connection Was Developed To Overcome the Failures That More Often Cause Trouble on the Fuel and Lubricant Lines of an Automobile Chassis than the Line Itself. The Tubing Nut Makes the Connection by Spinning the Inner End of the Tapered Sleeve against the Shoulder in the Connection, Slightly Indenting or Ringing the Tube at This Point. The Fillet in Nut Permits the Tubing To be Bent at a Sharp Angle when Leaving the Connection. Any Vibration Transmitted from the Tube to the Connection or Vice Versa Is Absorbed by the Nut, Which Has a Long Bearing or Support on the Tube, This Construction Preventing Vibration from Concentrating in the Connection at the Point on the Tube Where the Tapered Sleeve Has Weakened the Tube

Let us state the pressures developed by the pump in the form of a proportion, as $a : b :: c : 1$, in which a equals the pressure in pounds on the plunger, b equals the pressure in pounds per square inch in the main-supply line and c equals the area of the plunger, or 0.19635 sq. in. Then, if a man who weighs 150 lb. steps on the plunger, we have $150 : b :: 0.19635 : 1$, and $b = 763.9$ lb. per sq. in., which is the pressure on the oil in the main tubing-line. A sudden depression of the plunger will produce a pressure of 1200 lb. per sq. in. By holding to the steering-wheel and pressing down with the foot on the plunger, pressures of 2000 lb. per sq. in. can be attained. Three sizes of tubing are used in installing the system. One has a 5/16-in. outside diameter and a 0.050-in. wall, for the main tubing-lines between the pump and headers; another has a 3/16-in. outside diameter and a 0.050-in. wall, for delivery tubing-lines between the headers, and a third, which is of short length on the front axle, has a 3/16-in. outside diameter and a 0.065-in. wall.

We have made extensive experiments with tubes of various alloys, including aluminum, extending over a period of several years, and have finally developed a specialized tube that can be produced commercially with absolutely clean bores. Tubes of pure copper or of an alloy of 85 per cent of copper and 15 per cent of zinc give equally good results, although the alloy tube is slightly stiffer and harder to handle. This heavy-wall tubing is very strong, and it shows great ability to resist crystallization under vibration. In the 3/16-in. size it cannot be bent short enough to alter the area of its bore; any ordinary hammer-blow will not affect it materially. A length of this tube with a single coil of 2½-in. diameter at each end, attached to the front axle and to the chassis frame at the rear of the front spring-shackle, withstood the vibration and movement between the axle and the frame for 14,000 miles of car operation over all kinds of road. On a test machine that will be described later runs of 1000 hr. are reached frequently.

Failure of the gasoline and the oil tubing-lines on a chassis generally occurs in the tubing connection and not in the line itself. We have developed a type of tubing connection for use with the system which has not shown a single failure in thousands of miles of operation of many test cars. This connection is cheap to manufacture, the connections are easily assembled and fittings are practically eliminated, as part of the connection is made in the unit to which lubricant is supplied.

Fig. 2 shows this connection. It is made commercially by drilling a No. 15 hole, of 0.1800-in. diameter, sizing it with a special forming reamer and tapping it with a $\frac{3}{8}$ x 24 S.A.E. Stadard plug-tap. The tubing nut makes the connection by spinning the inner end of the tapered sleeve against the shoulder in the connection, slightly indenting or ringing the tube at this point. The fillet in the nut allows the tubing to be bent at a sharp angle when leaving the connection. Any vibration transmitted from the connection to the tube, or from the tube to the connection, is absorbed by the nut, which has a long bearing or support on the tube. This construction prevents the vibration from concentrating in the connection at the point on the tube where the tapered sleeve has weakened the tube.

Referring to Fig. 1, from the tubing connection at the base of the reservoir, a 5/16-in. main-supply tube extends to the header, which is a device that accurately measures and delivers a predetermined volume of oil every time the plunger of the pump is depressed. The control headers may have as many separate outlets as are required.

In Fig. 3, the main body of the header is a brass forging provided with a lug for attaching to the side-member of the frame by a $\frac{1}{4}$-in. S.A.E. Standard bolt, lock-washer and nut. The 5/16-in. main-supply tube is attached to the header with the standard tubing connection. Within the body of the header is a passage provided with spaced valve-seats between which a hardened double-ended tapered-valve having ends with a 30-deg. included angle is adapted to operate. A spring attached to the valve normally holds the valve closed against the supply passage. An air-chamber formed from a single piece of metal is attached to the header over the valve by a threaded portion and made oil-tight by a gasket. A header-tubing connection combining the outer delivery valve-seat and the delivery tube-connection is attached by a threaded portion and a gasket. In production, the distance between the face of the header and the shoulder of the inner valve-seat is held within close limits by a depth reamer provided with a shoulder; the hardened double-ended taper-valve with its spring is placed in the passage in the header; the header tubing-connection without its gasket is screwed into the header to the shoulder on the connection; and the tapered ends of the valve are forced into the softer metal of the header and the tubing connection, thus forming perfect seats approximately 1/64 in. wide. The header tubing-connection is then removed, a gasket 1/32 in. thick is placed on it and the connection is replaced in the header. All valves are thus adjusted automatically for a uniform end-travel of 1/32 in. In a multiple-outlet header, a common supply-passage is provided with as many valves, air-chambers and outlets as are required.

Operation

In operation, when the pump plunger is depressed, the oil is trapped in the cylinder and forced through the screen in the drain-plug passages and through the main-supply tube to the header; the shock or impact of the descending plunger is transmitted through the column of oil to the valve in the header, thus snapping the valve over against its spring pressure and closing the outlet from the header to the delivery tube; and the descending plunger forces oil up into the air-chamber over the valve, compressing the trapped air. At a pressure of 300 lb. per sq. in., the oil practically fills the air-chamber, as the air is compressed into such a small space that the space cannot be seen. When the pressure on the plunger is released, the double-ended valve, actuated by its spring and the air-pressure on the top of the oil in the air-chamber, darts back, closes the supply passage from the pump and opens the passage from the air-chamber to the delivery tube. The air under pressure in the air-chamber forces all of the oil in the air-chamber out through the delivery tube. The volume of oil delivered by a header outlet at each stroke of the plunger is approximately equal to the volumetric capacity of the air-chamber. The volumes of oil delivered by the header to each individual delivery-line are determined accurately by the size of the air-chamber installed on the particular line.

Because, in normal operation, the oil is forced to the bearings by compressed air, each outlet will deliver a few drops of oil under considerable pressure and continue to deliver oil at a slowly decreasing rate for several hours after the plunger is depressed. Immediately after depressing the pump plunger, the oil in the delivery tube is momentarily subjected to the same pressure as the pressure placed on the oil by the pump. When a small volume has been delivered by the compressed air in the air-chamber, the air expands rapidly and a continuously decreasing pressure is maintained on the oil in the delivery tube until the air-pressure in the air-chamber reaches a state of equilibrium with the atmospheric pressure. Under normal operation, pressures developed at the delivery-tube outlets vary from 1 to 10 lb. per sq. in., depending on the volume of oil delivered.

When any great resistance is offered to the flow of the oil through the delivery tube, the static condition of the oil in the header and the delivery tube will prevent the double-acting valve from transferring and closing the outlet from the header to the delivery tube. Under this condition the valve will bypass and the direct oil-pressure from the pump will be applied directly to that particular delivery-tube without affecting any of the other delivery-tubes, which will function as usual. Any predetermined volume of oil, from a single drop to any desired volume, is delivered positively at each outlet every time the plunger is depressed.

Accuracy of Oil-Control

To illustrate the accuracy with which the device will measure and deliver volumes of oil regulated by the volume of the air-chambers, a six-outlet header having six air-chambers with a combined volume capacity of 0.093 cu. in. was connected with a reservoir-pump unit having a reservoir capacity of 27 cu. in. The plunger was depressed 285 times to empty the reservoir. Mathematically, we have $27 \div 0.093 = 290$ strokes required to empty the reservoir, the variation being 5 strokes in 290 or 1.7 per cent. Failure or derangement in one or in any number of the delivery-tubes will not affect the operation of the other remaining delivery-tubes.

The type of valve used in the header will hold oil under pressure for long periods of time. When a gage is connected to one of the delivery outlets, a header will show pressure for several weeks without an appreciable loss of pressure.

A 7-ft. tube of 3/16-in. outside diameter and 0.05-in. wall-thickness, filled with a heavy gas-engine cylinder-oil having a pour-test of 38 deg. fahr., was maintained for 12 hr. at a temperature of 15 deg. fahr., and a pressure of 2000 lb. per sq. in. applied to this tube for 30 sec. failed to force oil through the tube. A header attached to a similar tube under the same time and temperature conditions delivered its predetermined volume of oil at the end of the tube after 3 hr. Using an oil of a pour-

test of approximately 0 deg. fahr., a test system was maintained at a temperature of from zero to 10 deg. below zero fahr. for 18 hr., and every outlet delivered its predetermined volume of oil after a single stroke of the pump plunger.

The device will measure accurately and deliver any grade for oil from a heavy cylinder-oil of high pour-test to an oil having a zero pour-test. We recommend the use of the same oil as that used in the engine, for temperatures of 15 deg. fahr. and above; for lower temperatures, an oil having a low pour-test is recommended. A four-outlet header was operated by a power pump that made 6 strokes per min., or 360 deliveries of oil at each outlet per hr. A test was run for 3 months, a total of 650 hr., and each outlet delivered oil 234,000 times. At the end of the test, each outlet was calibrated for volume delivered and found to be delivering its predetermined volume of oil. When removed, the air-control chambers were found to be free from oil and full of air.

Due to the construction of the pump, in which the cylinder has a long time-interval to fill with oil, and to the fact that the plunger moves a large volume of oil in

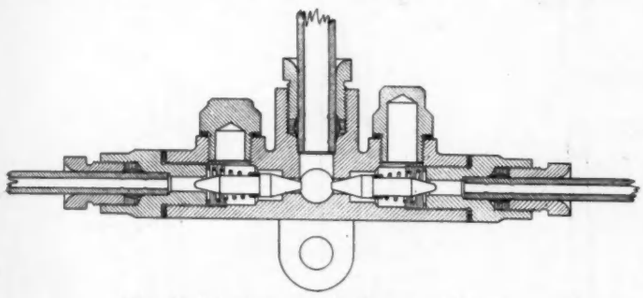

FIG. 3—SECTION OF THE CONTROL HEADER

This Device Accurately Measures and Delivers a Pre-Determined Quantity of Oil Every Time the Pump Plunger Is Depressed. The Main Body of the Header Is a Brass Forging That Is Attached to the Main-Supply Tube by a Standard Connection. Within the Body of the Header Is a Passage Having Spaced Valve-Seats between Which a Hardened Double-Ended Valve Operates. Normally This Valve Closes the Supply Passage, but When the Pump Plunger Is Depressed the Impact Transmitted through the Column of Oil Forces the Valve Over and the Oil Is Admitted into the Air Chamber above the Valve. When the Pressure on the Plunger Is Released the Valve Is Retracted to Its Normal Position by a Spring and the Oil Is Forced Out of the Air Chamber into the Delivery Tube

comparison with the volume delivered by each individual header-outlet, the device can be allowed to stand inactive for long periods of time and still will deliver accurately measured volumes of oil at every outlet at the first stroke of the pump plunger. The only derangement of any part of the system which will prevent a header outlet from delivering its predetermined volume of oil is the lodging of a particle of foreign matter or dirt between the inlet-valve of the header and its seat. When this condition occurs the oil under pressure in the air-chamber will return to the main-supply line instead of being forced through the delivery line. This condition affects only one outlet and, generally, will right itself since the next operation of the pump plunger will wash the foreign matter or the dirt through the header and clear the valve-seat. Foreign matter between the outlet-valve and its seat only causes that outlet to deliver a slightly larger volume of oil than is delivered normally. A 12-ft. length of the 3/16-in. x 0.05-in.-wall tube, filled with oil and having one end sealed, can be stood vertically with the open end at the bottom without any of the oil coming out of the tube. If the tube is connected to a rotating bearing in which a film of oil has been formed, approximately only 5 per cent of the volume contained in the tube will be drawn out.

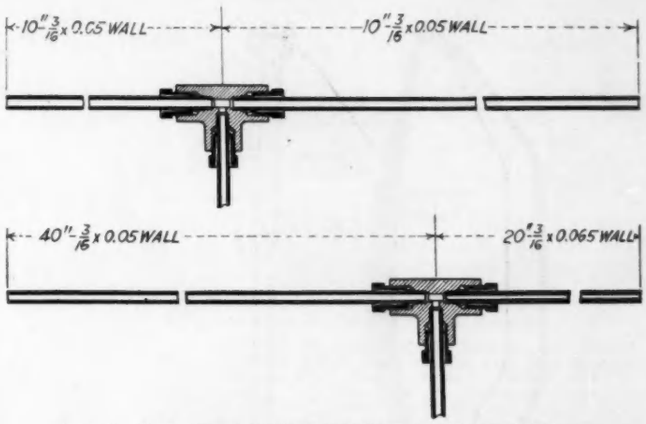

FIG. 4—SPLIT TUBE CONSTRUCTION THAT SIMPLIFIES THE INSTALLATION

This Construction Provides an Additional Control of the Volume of Oil Delivered by a Single Header-Outlet by Using Equal Lengths of the Same Size of Tubing To Cause Equal Volumes of Oil under the Same Pressure To Be Delivered at the Outlets as in the Upper View. If the Tubes on Either Side of the Tee Connection to the Header Outlet Are of Different Lengths and Sizes, as in the Lower View, the Volume of the Oil and the Pressure at Which It Is Delivered Must Be Equalized by Changing the Location of the Tee. This Latter Construction Is Employed on the Split Delivery Line That Supplies Lubricant to the Steering-Knuckles and the Tie-Rod Connections of the Front Axle

DETAILS OF CONSTRUCTION AND INSTALLATION

Fig. 4 shows an additional control of the volume of oil delivered by a single header-outlet. This construction is employed to simplify the installation. A measured volume of oil is delivered by the tube leading from a header outlet to the tee from which branched delivery-tubes extend to the bearings. By opposing tubes of equal length with tubes of equal bores, equal pressures and equal volumes of oil will be delivered at the respective outlets. By opposing tubes of unequal length with tubes of unequal bores, the tubing tee can be placed nearer one of the outlets and the pressure developed at the outlets and the volumes delivered at the respective outlets can be maintained equal. This latter construction is employed for the split delivery-line supplying lubricant to the steering-knuckles and tie-rod connections of the front axle.

Fig. 5 shows the tubing clips, comprising two similar pieces that clamp the tube or tubes between them; they are held together and to the frame by a machine screw and a square nut. To facilitate assembly, a long machine screw is used, the nut being held from turning by

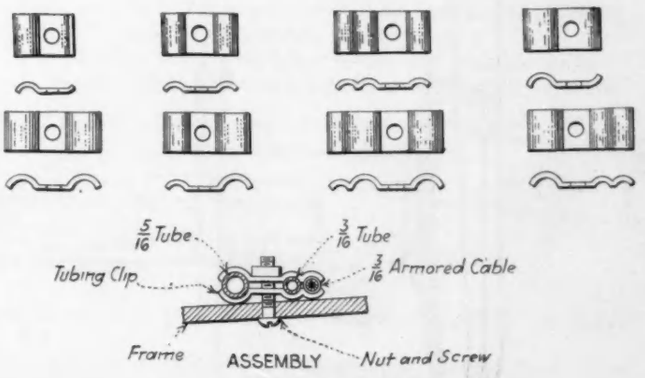

FIG. 5—TUBING CLIPS

These Comprise Two Similar Pieces Clamping the Tube or Tubes between Them and Held Together and to the Frame by a Long Machine-Screw and a Square Nut, the Latter Being Kept from Turning by the Outer Part of the Clip That Fits the Nut. When the Clip Is Set Up Tight the Projecting Screw Is Cut-Off and Riveted to the Nut by a Blow of a Hammer

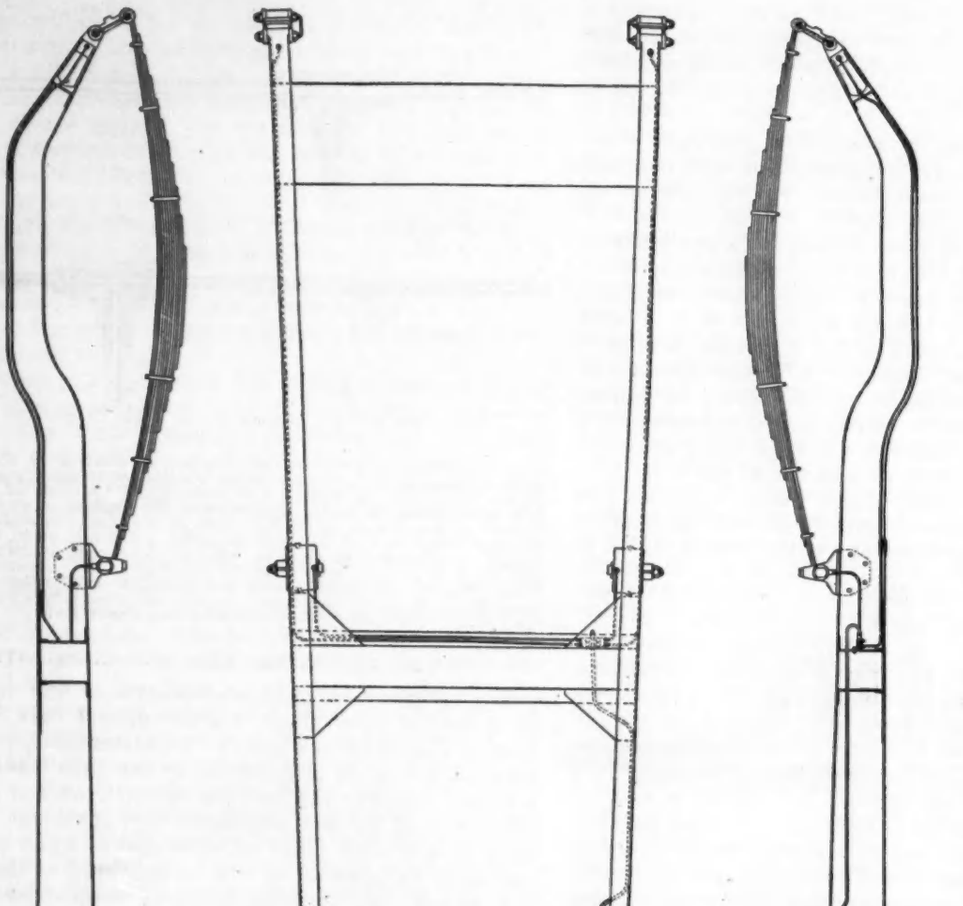

FIG. 6—SYSTEM INSTALLATION ON A CHASSIS OF CONVENTIONAL DESIGN

The Reservoir and the Pump Are Attached to the Frame So That the Plunger Projects through the Floor-Boards in Front of the Heel-Board of the Front Seat. Main Tubing-Lines Extend from the Pump to Three Headers, Each of Which Is Centrally Located with Respect to the Group of Chassis Points That It Lubricates. The Rear Header Supplies Oil to the Rear-Spring Front-Bolts and the Shackle Bolts through Four Outlets. The Left Front-Header Has Four Outlets and Lubricates the Left-Spring Front-Bolt, the Shackle Bolts, the Clutch Shaft and the Steering-Gear Case and Shaft and Both Ends of the Steering-Gear Connecting-Rod. The Right Front-Header Supplies Oil to the Right-Front Spring-Bolt, the Shackle Bolts and to the Steering-Knuckles and the Tie-Rod Ball-Sockets of the Front Axle. The Complete Installation Has Only One Moving Part, the Flexible Tube Extending from the Frame to the Front Axle. All Swivel Connections Having Been Eliminated

the outer part of the clip that fits the nut; when tight, the projecting screw is cut off and riveted to the nut with a blow of a hammer. The construction provides a fast, simple and neat method of supporting and securing the tubes of the lubricating system, the gasoline line, and wires.

Fig. 6 shows an installation of the system on a chassis of conventional design. The reservoir and pump unit is attached to the frame so that the plunger projects through the floor-boards in front of the heel-board of the front seat. From the pump, main tubing-lines extend to three headers, each located centrally with respect to the group of chassis points lubricated. The rear header, having four outlets, supplies oil to the rear-spring front-bolts and to the shackle-bolts. The left front-header, having four outlets, supplies oil to the left-spring front-bolt, the shackle-bolts, the clutch shaft and clutch collar, the steering-gear case, the steering-gear shaft and both ends of the steering-gear connecting-rod. The right

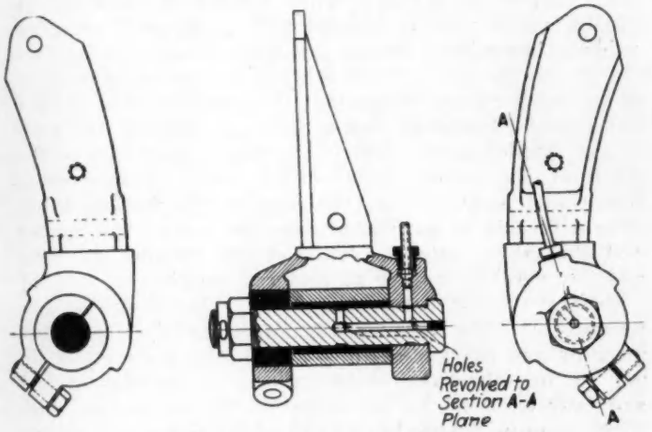

FIG. 7—FRONT-SPRING FRONT-HANGER

A Tubing Connection Is Machined on the Rear Side of the Inner Boss for the Spring Bolt, the Outer Boss Being Provided with a Clamping Bolt Holding a Split Sliding Plug Adapted To Take the Side Play between the Spring Eye and the Hanger. Two Annular Grooves in the Spring Bolt Are Provided with Radial Holes to a Longitudinal Central Hole That Is Plugged at the Head End. When the Bolt Is Installed in the Hanger, the Annular Groove in the Larger Diameter Provides a Passage for the Oil from the Tubing Connection in the Boss to the Longitudinal Central Hole, from Which Oil Passes through the Radial Hole to the Annular Groove at the Center of the Bearing Face. The Nut on the Bolt Is Drawn Up To Take Out the Side Play between the Spring Eye and the Hanger and the Sliding Plug Is Secured by Tightening Its Clamping Bolt

front-header, having three outlets, supplies oil to the right front-spring bolt, the shackle-bolts the steering-knuckles and tie-rod ball-sockets of the front axle. The complete installation has only one moving part, which is the flexible tube that extends from the frame to the front axle. Constructions are employed to lubricate the various chassis units in which swivel connections and moving parts and tubes are eliminated, and the tubing and the connections adequately protected. In general, all service-work can be carried on without disturbing the tubing or the connections of the lubricating system.

An installation similar to that shown in Fig. 6, on a 115-in. wheelbase chassis, requires 44 ft. of tubing to deliver the predetermined volume of oil to the 25 chassis bearings lubricated; 0.2454 cu. in. of oil is delivered at each stroke of the pump plunger to lubricate every chassis bearing thoroughly. Lubricating the chassis once for every 75 miles of operation, one filling of the reservoir with 50 cu. in. of oil will provide lubricant for 15,000 miles of car operation.

Taking up in detail the constructions employed to lubricate the different units of the chassis, Fig. 7 shows

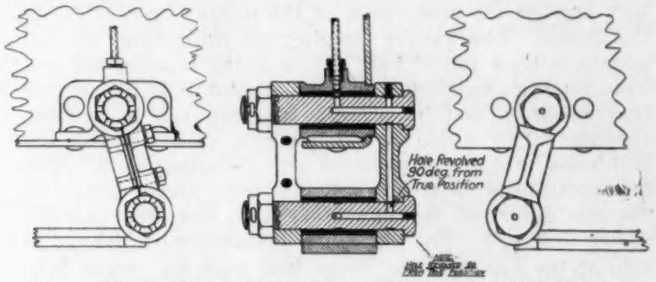

FIG. 8—THE SHACKLE HANGER AND THE SHACKLE

The Supply-Tubing Connection Is Made To a Boss on the Upper Part of the Hanger Bracket Inside the Frame and the Hanger Bushing Has an Outside Annular Groove with a Radial Hole to the Inner Bearing-Surface. The Top Bolt Is Installed with the Radial Hole at the Top and the Lower Bolt with the Radial Hole at the Side. The Outside Annular-Groove of the Top Bushing Permits the Installation of the Bushing in Any Position without Closing the Oil Passage from the Tubing Connection to the Bearing. Part of the Oil Is Retained in the Annular Groove at the Center of the Upper-Bolt Bearing-Surface To Lubricate the Upper Bolt, while the Remainder Is Forced through the Radial Hole to the Center of the Bolt and through a Drilled Passage in the Outer Shackle-Plate to the Lower Bolt where It Passes Out through the Radial Hole at the Side to the Annular Groove around the Bolt at the Center of the Bearing

a front-spring front-hanger. A tubing connection is machined on the rear side of the inner boss for the spring-bolt. The outer boss is provided with a clamping bolt holding a split sliding plug adapted to take up the side-play between the spring-eye and the hanger. The spring-bolt has a hexagonal head that is held from turning by a projecting lug on the inner face of the hanger. It is ground in two diameters; the larger diameter passing through the inner boss is from 0.003 to 0.005 in. oversize to provide an oil-tight fit in the boss; the remainder of the bolt has a diameter to allow from 0.0015 to 0.0030-in. running clearance in the bushing. Two annular grooves are provided with radial holes leading to a longitudinal central hole that is plugged at the head end. When the bolt is installed in the hanger, the annular groove in the larger diameter which makes-up oil-tight in the inner boss provides a passage for the oil from the tubing connection in the boss to the longitudinal central hole from which the oil passes through the radial hole to the annular groove at the center of the bearing face. The nut on the bolt is drawn-up to take out the side-play between the spring-eye and the hanger, and the sliding plug is secured by tightening its clamping bolt. The spring-bolt can be serviced without disturbing the connections of the lubricating system. The tubing connection and the tube are protected by the hanger and the frame and cannot be damaged, short of a collision that would wreck the hanger.

Fig. 8 shows the construction of the shackle hanger and the shackle. The supply-tubing connection is made

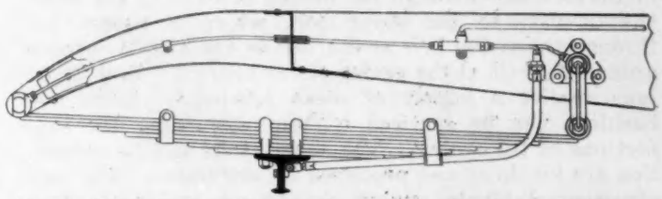

FIG. 9—FLEXIBLE TUBE EXTENDING FROM THE FRAME TO THE FRONT AXLE

This Tube Is a Combination Comprising a Flexible Metal Tube That Has Been Covered with a Layer of Extruded Rubber over Which a Diagonal Cord Is Tightly Braided and Then Covered with an Outside Layer of Extruded Rubber, the Complete Tube Now Being Vulcanized. One of These Tubes Was Tested for 1724 Hr., during Which Time It Withstood 74,476,800 Single Flexes, and Was Then Subjected to an Oil Pressure of 3000 Lb. for 1 Hr., Without Developing a Leak or Failing in the Connection. When Installed as Shown the Tube Is Supported by a Flexible-Tubing Clip Attached to the Rebound Clip of the Front Spring and Is Under a Continuous Oil-Pressure of 12 Lb.

to a boss on the upper part of the hanger bracket inside the frame. The hanger bushing has an outside annular groove with a radial hole to the inner bearing-surface. The outside shackle-plate has a drilled hole connecting the bolt-holes and lugs for preventing the bolts from turning. The inside shackle-plate is split between the bolt-holes and provided with two clamping-bolts. The hexagonal-head bolts are of the same construction as the one described in connection with the front hanger shown in Fig. 7. The top bolt is installed with the radial hole at the top, and the lower bolt with the radial hole at the side. The outside annular groove of the top bushing permits the installation of the bushing in any position without closing the oil passage from the tubing connection to the bearing. Part of the oil supplied through the supply-tubing connection is retained in the annular groove at the center of the upper-bolt bearing-

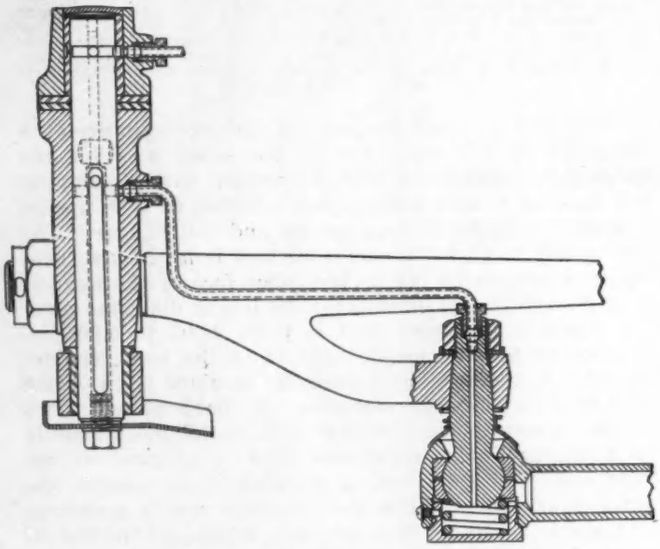

FIG. 10—HOW THE STEERING-KNUCKLES AND THE BALL SOCKETS OF THE FRONT-AXLE TIE-ROD ARE LUBRICATED

The Supply Tube Is Attached to a Connection Machined in the Rear Surface of the Upper Boss of the Axle Fork. Oil from the Supply Tube Passes around the Outside Annular-Groove of the Upper Steering-Knuckle Bushing and through a Radial Hole to the Annular Groove at the Upper End of the Steering-Knuckle Pivot where It Lubricates the Upper Bearing and Works Down and Lubricates the Thrust Washers between the Steering-Knuckle and the Axle Fork. Part of the Oil Passes through the Radial Hole in the Pivot to the Central Longitudinal Hole and Out through the Radial Holes at the Center of the Pivot, Part Going to the Tie-Rod Ball-Socket through the Connecting Tube and the Remainder to the Surface of the Pivot and down the Groove To Lubricate the Lower Steering-Knuckle Bushing

surface to lubricate the upper bolt. The remainder of the oil is forced through the radial hole to the center of the bolt and through the drilled passage in the outer shackle-plate to the lower bolt, where it passes out through the radial hole at the side to the annular groove around the bolt at the center of the bearing. Both bearings receive a supply of clean lubricant. Bolts and bushings can be serviced without disturbing the connections of the system. The supply tube and its connection are inside of and protected by the frame. The construction eliminates swivel connections and protruding fittings that are broken off easily. Other shackle constructions have been employed in which a knurl under the bolt head prevents the bolt from turning, and a U-shaped tube, attached by standard tubing-connections to the bolts, conducts oil from the upper to the lower bolt.

A construction similar to that shown in Fig. 7 can be employed for the front hanger of the rear spring with the feed line attached to the inner boss, the outer boss having a clamping bolt for holding a split sliding-plug to take-up the side-play between the spring-eye and the hanger. The spring-bolt can be serviced without disturbing the tubing connections, which are inside of and protected by the frame. A construction similar to the shackle construction shown in Fig. 8 is recommended for the rear-spring hanger and the shackle. Fig. 9 shows the installation of the flexible tube that extends from the frame to the front axle. It is supported by a flexible-tubing clip attached to the rebound-clip of the front spring.

FLEXIBLE-TUBE CONSTRUCTION

We have experimented with and tested practically every known type of flexible-tube construction. As a result of these tests we have developed a flexible tube for use with lubrication systems which will give satisfactory service when installed properly. This tube is a combination, comprising a flexible metal tube lined with rubber and a fabric outer protective covering. A flexible metal tube is covered with a layer of extruded rubber, then a layer of diagonally cored fabric is braided tightly on the inner rubber layer and an outside layer of extruded rubber is applied; the complete tube is then vulcanized. Standard connections are used at the ends of the flexible tube. A 3/16-in. tube is threaded to the pitch of the convolutions of the inner flexible metal lining and screwed into the end of the flexible tube; then a ferrule is contracted over the end of the rubber and the fabric outer layers, and the ferrule, the tube and the metal lining are all soldered together.

Several flexible tubes, tested for 1 hr. under an oil-pressure of 3000 lb. per sq. in., were installed on a test machine and maintained under an oil-pressure of 12 lb. per sq. in.; then the center of the spring was raised and lowered 3 in. by an eccentric 360 times per min. After running 7 months, a total of 1724 hr., and having withstood 74,476,800 single flexes, the tubes were removed intact from the test machine. They were tested for 1 hr. under an oil-pressure of 3000 lb. per sq. in. without developing any leak or failure in the connections. All of the tubes were in good condition at the end of the test run and were available for continued service.

The flexible-tubing lead is attached to a tubing tee on the rear of the front axle inside of the left front-spring clip by a ¼-in. S.A.E. Standard bolt and lock-washer, a 17/64-in. hole being drilled through the axle web for the bolt. From this tee a short length of 3/16-in. tubing with a 0.065-in. wall extends to a tubing connection machined on the rear side of the upper boss of the right axle-fork. From the other side of the tee, a long length of 3/16-in. tubing with a 0.05-in. wall extends to a similar connection in the upper boss of the left axle-fork. The tube is placed in the axle web and attached by three clips requiring three ⅛-in. holes in the web. It is protected entirely from damage by the axle. As explained in connection with Fig. 4, equal pressures are developed and equal volumes of oil are delivered at the outlets in the respective axle-forks.

DETAILS OF LUBRICATING SPECIAL PARTS

Fig. 10 is a section showing the method of lubricating the steering-knuckles and ball-sockets of the tie-rod of the front axle. The supply tube is attached to a connection machined in the rear surface of the upper boss of the axle-fork. The upper steering-knuckle bushing is provided with an outside annular groove and a radial hole extending from the annular groove to the inside bearing-surface. The bushing provides a shoulder for

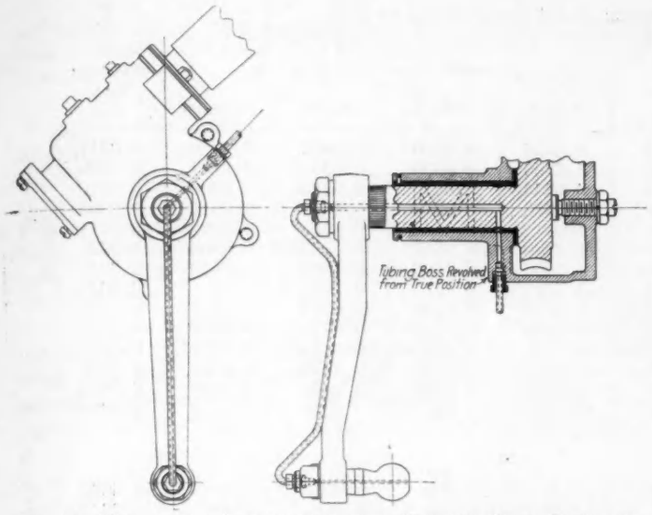

FIG. 11—METHOD OF LUBRICATING THE STEERING-GEAR CASE AND SHAFT AND BOTH BEARINGS OF THE STEERING-GEAR CONNECTING-ROD

A Tubing Connection Is Machined in the Upper Part of the Steering-Gear Case over the Bearing for the Shaft and an Outside Annular-Groove with a Radial Hole to the Inner Bearing-Surface Is Provided in the Steering-Gear Shaft Bushing. The Shaft Has an Annular Groove and a Radial Hole Extending from the Annular Groove to a Central Longitudinal Hole Extending from the Gear Case to a Tubing Connection Machined in the End of the Shaft to Which the Steering-Gear Arm Is Attached. A Tube Extends from the Connection in the End of the Shaft to Another That Is Machined in the Threaded End of the Ball Stud Attached to the Lower End of the Steering-Gear Arm by a Nut and a Special Lock-Washer

a Hubbard plug that makes an oil-tight joint at the top of the bearing. The steering-knuckle pivot has an annular groove near the upper end, and a radial hole extending into a longitudinal central hole that extends to the bottom of the pivot; the lower half of the hole is larger in diameter and is threaded at the lower end. A radial hole at about the center of the pivot extends through to both surfaces, together with another radial hole at a right angle and just above that extends to a surface flat or groove running downward to the lower steering-knuckle bearing. A tubing connection is machined in the rear surface of the steering-knuckle opposite the lowest radial hole in the steering-knuckle pivot; from this connection a tube extends to a connection machined in the top of the tie-rod ball-stud that has a hole drilled through its center and is secured in the steering-knuckle arm by a nut and a special lock-washer. A drip-pan is attached by a cap-screw and two packing-washers to the lower end of the pivot to carry any overflow of oil clear of the tire.

The annular groove and the radial hole in the upper steering-knuckle bushing permit installing the bushing in any position without closing the oil-passage from the supply-tubing connection to the bearing. Oil from the supply tube passes around the outside annular groove of the upper steering-knuckle bushing and through the radial hole to the annular groove at the upper end of the steering-knuckle pivot, where it lubricates the upper bearing and works down and lubricates the thrust-washers between the steering-knuckle and the axle-fork. Part of the oil passes through the radial hole in the pivot to the central longitudinal hole and out of the radial holes at the center of the pivot and part goes to the tie-rod ball-socket through the connecting-tube; the remainder of the oil goes to the surface of the pivot and down the flat or groove to lubricate the lower steering-knuckle bushing. The well in the lower part of the pivot provides a trap for any sediment or dirt. The lower bushing, being open at the bottom, allows the oil to work through continuously and carry away dirt and particles abraded from the bearings, preventing the oil passages from becoming stopped-up.

The same steering-knuckle pivot can be used in both right and left steering-knuckles. The front axle can be removed from the chassis by disconnecting the flexible tube attached at the tee on the axle. All other service-work on the axle, except that of removing the tie-rod ball-stud and the steering-knuckle arm, can be carried on without disturbing the tubing and the connections of the lubrication system. The construction eliminates all moving parts and swivel connections. The tube connecting the steering-knuckle and the tie-rod bearing is protected adequately from damage by the knuckle and the arm, and moves with it as a unit according to the motion of the steering-knuckle.

Fig. 11 shows the method employed to lubricate the steering-gear case, the shaft and both bearings of the steering-gear connecting-rod. A tubing connection is machined in the upper part of the steering-gear case over the bearing for the shaft, and an outside annular groove

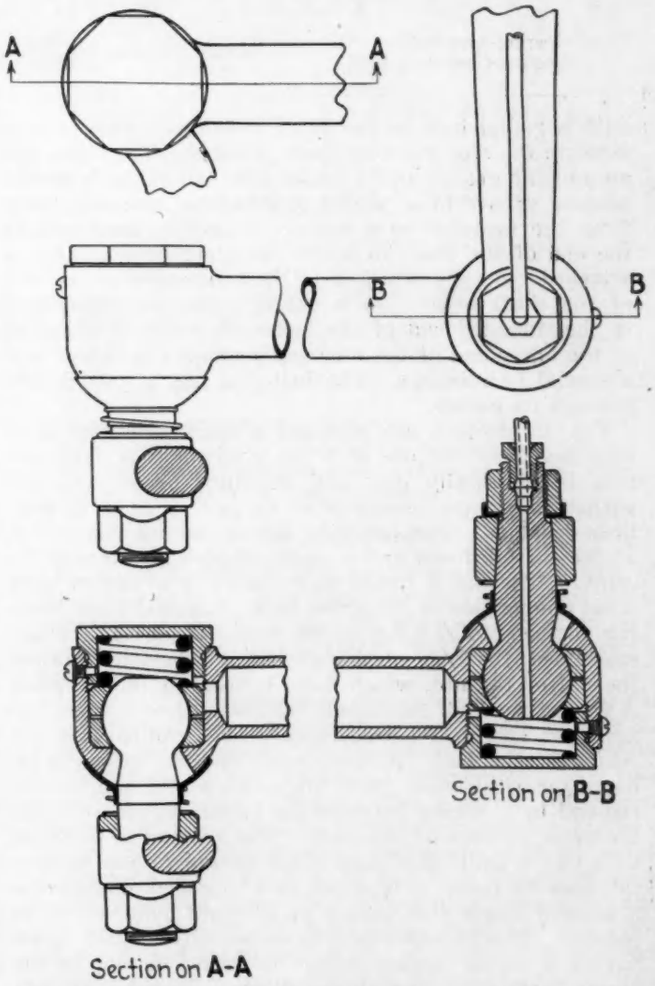

FIG. 12—A BALL STUD AND SOCKET THAT HAS BEEN DEVELOPED FOR USE WITH THE SYSTEM

The Construction Is Practically Dirt and Moisture Proof and Will Withstand an Oil Pressure of 25 Lb. with Very Little Leakage. The Design and the Method of Assembly Make a Safe Construction Since the Ball Stud Can Only Be Removed from the Rod-End by Disconnecting It from the Steering-Gear Arm and Passing It through the Rod-End. Oil Supplied to the Connection on the Steering-Gear Case Lubricates the Shaft in Its Bearing, Passes through the Radial Hole to the Central Shaft-Hole and through the Tube to the Ball Socket. Oil from the Rear End of the Steering-Gear Connecting-Rod Flows Forward and Bathes the Front Ball-Socket when the Chassis Is Operated on a Down Grade

TABLE 1—CHASSIS-PARTS WEAR AFTER 24,444 MILES OF CAR TRAVEL

Location of Bearing	Diameter When New, In.	Diameter After Test Run, In.				Average Wear, In.
		Outside	Center	Inside	Average	
Right Front-Spring, Front	0.634 to 0.633	0.6328	0.6330	0.6330	0.6329	0.0011
Left Front-Spring, Front	0.634 to 0.633	0.6330	0.6330	0.6333	0.6331	0.0009
Right Front-Shackle, Top	0.634 to 0.633	0.6335	0.6320	0.6335	0.6330	0.0010
Right Front-Shackle, Bottom	0.634 to 0.633	0.6315	0.6320	0.6310	0.6315	0.0025
Left Front-Shackle, Top	0.634 to 0.633	0.6315	0.6338	0.6335	0.6329	0.0011
Left Front-Shackle, Bottom	0.634 to 0.633	0.6280	0.6315	0.6333	0.6309	0.0031
Right-Front Rear-Spring	0.751 to 0.750	0.7500	0.7500	0.7500	0.7500	0.0010
Left-Front Rear-Spring	0.749 to 0.748	0.7475	0.7475	0.7465	0.7471	0.0019
Right Rear-Shackle, Top	0.634 to 0.633	0.6315	0.6290	0.6310	0.6305	0.0035
Right Rear-Shackle, Bottom	0.634 to 0.633	0.6300	0.6310	0.6310	0.6307	0.0033
Left Rear-Shackle, Top	0.634 to 0.633	0.6325	0.6320	0.6335	0.6327	0.0013
Left Rear-Shackle, Bottom	0.634 to 0.633	0.6300	0.6310	0.6330	0.6313	0.0027
Right Tie-Rod	0.624 to 0.623	0.6230	0.6230	0.6225	0.6228	0.0012
Left Tie-Rod	0.624 to 0.623	0.6225	0.6227	0.6220	0.6224	0.0016
			Top	Bottom		
Right Knuckle-Pivot	1.02 to 1.01	.....	0.999	0.9985	0.9988	0.0035
Left Knuckle-Pivot	1.02 to 1.01	.....	0.999	0.9985	0.9988	0.00350
Average Wear for 16 Bearings, in	.....	.....	.....	.....	.....	0.00207
		Across Wear, In.				
Steering-Arm Ball	0.990	0.982				
Steering-Gear-Arm Ball	0.990	0.986				

with a radial hole to the inner bearing-surface is provided in the steering-gear-shaft bushing. The shaft has an annular groove and a radial hole extending from the annular groove to a central longitudinal hole extending from the gearcase to a tubing connection machined in the end of the shaft to which the steering-gear arm is attached. A tube attached to the connection in the end of the shaft extends to a tubing connection machined in the threaded end of the ball-stud, which is attached to the lower end of the steering-gear arm by a nut and a special lock-washer. The ball-stud has a hole drilled through its center.

Fig. 12 shows a ball-stud and a connection that have been developed for use with the system. The construction is practically dirt and moisture proof and will withstand an oil-pressure of 25 lb. per sq. in. with very little leakage. The ball-stud has a tubing connection at the threaded end and a small oil-passage through its center. The nut is locked on the stud by a washer with a flat on one side of its center hole; it is held from turning on the stud by a flat on the threaded portion. When assembled, the edge of the washer is turned-up against the flat of the nut, which locks it securely on the stud. A forged rod-end, electrically butt-welded to a tube, has an upper spherical surface turned on a radius with the center of the ball. A dust-cover, sliding on the stud, has a spherical lower part; the cover is held against the rod-end by a spring between the steering-gear arm and the upper surface of the cover. The rod-end is provided with two cylindrical sliding plugs having ground spherical inner surfaces; it is closed by a threaded plug having a tapered flange that makes an oil-tight joint with the rod-end. This threaded plug is locked with a small screw having a copper gasket under its head. A slot in the upper surface of the threaded plug provides an oil-passage from the space below the ball to a hole that connects with the tube extending to the other ball-stud connection. A spring between the threaded plug and the lower sliding-plug on the ball maintains the moving parts in contact and takes-up wear. The ball-stud is assembled in the connection from the bottom.

The design and the method of assembly make an absolutely safe connection, as the ball-stud can be removed from the rod-end only by disconnecting it from the steering-gear arm and passing it through the rod-end. Oil supplied to the connection on the steering-gear case lubricates the shaft in its bearing and passes through the radial hole to the central shaft-hole and through the tube to the ball-socket. Oil from the rear end of the steering-gear connecting-rod flows forward and bathes the front ball-socket when the chassis is operated on a descending grade. All service-work on the steering-gear and the steering-gear connecting-rod can be accomplished by disconnecting three tubing connections. The tubes and the connections move with the parts lubricated and are amply protected from damage. In connection with installations that have been made, satisfactory means have been worked out to supply lubricant to practically all conventional constructions employed in motor-car design.

Flushing and Wear

The oil in any lubrication system, in its tubes and in the bearings supplied by the system, will in time become thick and gummy, but by pumping kerosene freely through the headers of this system all of the thickened oil and the sediment that has accumulated in the oil-passages and the bearing surfaces can be flushed out.

Table 1 shows the amount of wear on the chassis parts of a chassis equipped with this lubricating system after 24,444 miles of road operation covering 2 years of driving. The car was stored in a cold-garage in winter with sustained temperatures of below 0 deg. fahr., using a heavy gas-engine cylinder-oil having a pour-test of 38 deg. fahr. The bolts were made from tool steel, 55 hard by the Shore test. Measurements were taken on the bolts at the points of their greatest wear, and the system was flushed with kerosene after each 4000 miles of car travel. The upper bolts of the spring-shackles were operated direct in a malleable hanger having no bushing; the remainder of the bolts were operated in bronze bushings. Bolts having a bearing in malleable iron quickly assume a scored appearance on the bearing surface, although the wear is approximately

(*Concluded on p. 445*)

Discussion of Papers at the 1924 Annual Meeting

THE discussion of the papers presented at the Aeronautic and the Brake Sessions of the 1924 Annual Meeting included written contributions submitted by members and the remarks made at the meeting. In every case an effort has been made to have the authors of the several papers reply to the discussion, both oral and written, and these comments, where received, are included in the discussion. For the convenience of the members, a brief abstract of each paper precedes the discussion, with a reference to the issue of THE JOURNAL in which the paper appeared, so that members who desire to refer to the complete text as originally printed and the illustrations that appeared in connection therewith can do so with a minimum of effort.

It is expected that the papers by W. S. James and by A. A. G. Fokker will be printed in full in an early issue of THE JOURNAL, and the publication of the discussion that followed their presentation is therefore deferred.

NOTES ON A SAND-CAST ALUMINUM-COPPER-NICKEL-MAGNESIUM ALLOY

BY LIEUT. A. J. LYON, U. S. A., AND SAMUEL DANIELS

THE importance of the development of a light alloy for use in parts that are subjected to elevated temperatures has already been emphasized in many papers, among which that by S. D. Heron on Air-Cooled Cylinder Design and Development[1] should be particularly mentioned. It was with this purpose in view that the foundry of the Engineering Division of the Air Service at McCook Field undertook a brief survey of the alloying, the casting, the heat-treatment, the physical properties and the metallography of an aluminum-copper-nickel-magnesium alloy of the Magnalite type as sand-cast under ordinary foundry conditions.

It was found that the alloying involved no particular difficulty. The casting, however, showed the necessity for proper pouring temperatures, gating and placing of the chills and the risers. Several photographs are shown illustrating satisfactory and unsatisfactory methods of molding pistons and air-cooled cylinder-heads.

The heat-treatment of these alloys must be carefully conducted, since not only is the alloy tender at the quenching temperature, but it is also very susceptible to small variations in quenching temperature. With proper attention to manipulation, consistent results can be always obtained; and rejections from warpage and distortion are negligible. The treatment best combining the factors of physical properties and economy is to heat the alloy at 975 deg. fahr. for 5 hr. and then to quench in boiling water or air according to the design of the casting. The alloy is subsequently aged at 212 deg. fahr. for 16 hr., an overnight treatment.

The physical properties of this alloy at ordinary temperatures as cast are very much improved by suitable heat-treatment; and at 600 deg. fahr. the alloy shows the remarkable properties of being slightly stronger than it is at room temperature either as cast or heat-treated. The extended heat-treatments partaking of the nature of the malleablizing process in cast iron produce even better results than the short treatment described above, but the former is probably not economically justifiable, although it produces ultimate tensile-strengths as high as 45,000 lb. per sq. in. and Brinell hardness values as high as 105.

The average properties of the sand-cast and heat-treated alloy compared with some of the better known light casting-alloys are as tabulated below.

Alloy	Aluminum-Copper-Nickel-Magnesium		8 Per Cent Copper, 92 Per Cent Aluminum	10 Per Cent Copper, 90 Per Cent Aluminum
Condition	As Cast	Heat Treated	As Cast	As Cast
Ultimate Tensile-Strength, lb. per sq. in.	25,020	37,220	20,670	20,600
Brinell Hardness	74	93	52	58
Elongation in 2 In., per cent	0.7	1.1	2.0	1.2
Specific Gravity	.....	2.73	2.83	2.84

The metallography of the alloy is quite complex. A number of photomicrographs are included which not only show the constituents, but the changes in structure resulting from heat-treatment. [Printed in the February, 1924, issue of THE JOURNAL.]

[1] See THE JOURNAL, April, 1922, p. 244.

THE DISCUSSION

H. A. HUEBOTTER:—Has the cross-sectional area of this material any effect upon the unit tensile-strength, as is true of cast iron; that is, will a small section of it have a finer grain and a higher tensile-strength than a large section?

LIEUT. A. J. LYON:—Yes, the cross-sectional area has a very great effect on it both in the as-cast and in the heat-treated condition. In the latter, when the material is heated-up to the quenching temperature and then quenched, the rate of cooling has a rather pronounced effect upon the resulting physical properties; so, in a heavy section, the physical properties will be correspondingly low. In fact, it has been found in large castings in the 8-per cent copper-aluminum alloy that the tensile strength is lowered almost 50 per cent. The effect of heat-treatment of the aluminum-copper-nickel-magnesium alloy is to diminish the inequalities in physical properties peculiar to the alloy as cast. I do not have the results on any very heavy sections in that alloy, because we have restricted its use to pistons and cylinders, and the dimensions of the heaviest section in a cylinder are about ¾ in., but in a section of that weight we develop practically the same properties as we do in the separately sand-cast test-specimens.

W. C. KEYS:—What effect have the prolonged rather

high temperatures at which these parts are operated in the engine on the physical properties that were obtained by this previous heat-treatment?

LIEUTENANT LYON:—We have no data on this alloy regarding the hardness after it has been in an engine for, say, a period of 100 hr., although we have results on the straight copper-aluminum alloy with about 25 per cent magnesium, Lynite 122. We have found in some tests that the drop in the Brinell hardness across the crown of the pistons is almost 45 points. Unfortunately, we have not the same information on the aluminum-copper-nickel-magnesium alloy, but our tensile tests have shown that when the alloy is heat-treated it retains its strength at elevated temperatures; and we naturally infer from our temperature tests that involve continued exposure at 600 deg. fahr. that the reduction in hardness and strength will be less than in the case of the other alloys.

F. W. ANDREW:—Do you have any trouble due to lack of uniformity in casting this material?

LIEUTENANT LYON:—It is somewhat more difficult to cast than the straight copper-alloy, and our results on pistons and on cylinder-heads have shown that we obtained remarkably uniform results. I have data on a large number of heats and on tests on pistons and cylinder-heads over a period of about 2 years; the range in tensile strength for the heat-treated alloy is from 35,000 to 40,000 lb. per sq. in. and the Brinell-hardness range is within ± 10 points of a Brinell hardness of 95; that is, 85 to 105. We do not interpret results closer than $\pm$ 10 points for an aluminum alloy; so, our results for this alloy are remarkably uniform, provided the proper precautions are taken in pouring, gating and chilling. Chilling is very important in the use of this alloy.

J. W. GALLOWAY:—How well does this metal resist salt water?

LIEUTENANT LYON:—It is in about the same class as duralumin. On the basis of corrosive resistance, the aluminum alloys can be grouped roughly into about three divisions: First, the silicon alloys; that is, alloys containing appreciable amounts of silicon such as Alpax metal, having 13 per cent of silicon, and an alloy containing 5 to 6 per cent of silicon that I think is included in Army Ordnance specifications. Second, the duralumin type of alloys, containing approximately 4 or 5 per cent of copper and small amounts of magnesium and the aluminum-copper-nickel-magnesium alloys. Third, the 8 to 10-per cent copper alloys with or without magnesium, which are well known.

FOUR-WHEEL BRAKES

BY HENRI PERROT

FOLLOWING a review of four-wheel-brake development, the author quotes from a scientific note relative to four-wheel-braking action on a car that is rounding a curve, published by the French Academy of Science, and the conclusion therefrom that front-wheel brakes have a direct retarding effect on the motion of translation but, in addition, a direct retarding effect upon the instantaneous motion of rotation of the car about its own center of gravity. Further, from another article, he quotes authority for the theoretical advantage of four-wheel brakes on heavy down-grades.

Subsequent to an amplified statement that satisfactory operation of a four-wheel-brake system, from the driver's viewpoint and with reference to pedal-travel and pedal-pressure, constitutes the real problem, comparisons are made between internal-expanding and external-contracting types and the servo-brake is discussed with special reference to the Perrot system. The advantages of the author's four-wheel-brake system are set forth specifically, brake-system design is discussed in general and comments are made upon brake-lining, front springs and various precautionary measures that must be incorporated. He explains his non-use of equalizers and cites seven specific important items that should govern all four-wheel-brake design, as well as stating his ideas regarding the future development of the motor-car chassis, as affected by the present trend of brake-system practice. [Printed in the February, 1924, issue of THE JOURNAL.]

THE DISCUSSION

R. K. JACK:—Does diagonal compensation of brakes interfere with steering in any way? If not, why has it been discarded?

HENRI PERROT:—I still believe that diagonal braking is best, but I have not been able to find an engineer who felt that my point was right and who would try that diagonal braking. I think it is the simplest proposition of all because, when using diagonal braking which allows the outside wheel to be braked less than the inside wheel, you automatically relieve the rear wheel; so, you always have two wheels rotating, and you can never slide a car.

J. G. VINCENT:—I would like to know just why the outside front-wheel brake should be released in rounding curves with a car. Of course, due to the peculiar geometry, or better, the kinematics of the conventional front-axle steering system, when rounding a curve, the inside wheel is turned through a greater angle from the central position than the outer wheel; therefore, when the brakes are adjusted fairly close, the inner wheel is applied harder than the outer if no equalizer between the front brakes is provided.

When the car is rounding a curve, the motion may be resolved into translation of the center of gravity and rotation about the center of gravity. The instantaneous center of rotation of the car as a whole will lie on the prolongation of the rear axle, if the assumption can be made that the steering motion is perfect. However, this does not alter the problem for, if the steering motion is not perfect, the instantaneous center will be at a point that is not on the prolonged axis of the rear axle. However, so long as the instantaneous center is not on a line passing through the center of gravity perpendicular to the long axis of the car, the translation of the center of gravity will be composed of two components, one parallel and the other perpendicular to the long axis of the car. The system of forces acting on the car will be composed of those due to the acceleration of translation and a moment due to the angular acceleration.

All the external forces, which are applied at the wheels, acting on the car must comprise a system of forces that is in equilibrium with the forces of rotation and translation just described. All goes merrily on until some limiting condition is reached; that is, the car is in perfect control of the driver until the critical

braking-force of certain wheels is reached. When the brakes are applied, the braking effort of the rear wheels affects the motion of translation along the long axis of the car. The braking action of the front wheels when both front-wheel brakes are acting affects the translation and, to varying degrees, depending on the position of the front wheels; the forces of transverse translation, the centrifugal forces, and the steering moment are reacted in varying degrees by all four wheels due to resistance offered by side-skidding. Whenever the brakes are applied, it does not matter what shape of curve is followed by the center of gravity of the car so long as it is not a straight line, and we have the forces of translational and rotational acceleration acting in equilibrium with the external forces.

Assume now that the brakes are adjusted so that each wheel has a braking effort exactly proportional to the static weight on the tire, or, better, the general American practice of adjustment in which the rear wheels become locked before the front wheels do when the brakes are applied. Under such a condition, the moment of rotation becomes a serious factor in the production of rear-end skids when critical conditions are reached and, to offset this properly, the *outer* front-wheel brake should exert its greatest effort if this rear-end skidding is to be eliminated. If the outer front-brake is released, or partly released, and the inner front-wheel brake is applied proportionally harder, we have in addition to the moment of rotation another moment with considerable magnitude which adds up directly with the moment of rotation and, therefore, augments the moment of rotation. The effect of this is the production of rear-wheel skids with greater ease, at lower braking rates and on turns of less curvature.

We have gone so far in analyzing this problem as to write the equation of the path of the car under these conditions; the results of this analysis are covered by the following summary:

(1) All things being equal, such as car-speed, road conditions and the like, the loss of directive control of the car is greater with rear-wheel than with front-wheel skidding. At low speeds neither kind of skidding is serious but, at high speeds, the control, once lost, cannot be recovered with rear-wheel skids; with front-wheel skids, no change in the quality of the momentum of the car takes place and, hence, the control is recoverable by releasing the brakes somewhat

(2) In braking systems such that the majority of the braking action takes place on the rear wheels, locking the rear wheels controls the point where skidding commences. Under such conditions, the car will move in a straight path only so long as the rear wheels are perfectly equalized

(3) With the rear wheels locked and with the car moving in a straight path, the rear end will skid just as soon as a turning tendency is exerted on the car. This may arise from unequalized front-brakes or due to any deviation of the front wheels from the path of motion of the car. This peculiar action of the car under these conditions may be likened to the juggling of a straight rod on its end. So long as the rod is kept in the position where the center of gravity is directly above the point of support, nothing happens, but the slightest displacement of the center of gravity from the true vertical causes an increased displacement and the rod topples over; in other words, the condition is unstable. At low speeds an experienced driver can compensate somewhat for these turning-moments, but at high speeds with a sudden deviation the car gains considerable angular momentum when the skidding commences; generally, the car turns through a very large angle and comes to a stop before the driver realizes what has happened

(4) With the rear wheels locked and rounding a curve, the release of the outer front-brake applies a considerable turning-moment on the car which, acting in addition to centrifugal forces, greatly augments the turning tendency of the steering forces; hence, the rear wheels skid out much more easily

(5) Due to the loss of braking effort of the front wheel, which is released, the deceleration of the car is much lower and the critical skidding-point occurs at low braking rates

(6) It can be shown mathematically that, with two cars having the same distribution of weight and of braking effort for straight-ahead driving, all other conditions being equal, the car that does not release the outer brake can turn a shorter curve without skidding than the other car

(7) The above summary is based upon a comparison of two cars that are identical except for the way in which the brakes are applied. Another very important element has been found in mathematical analysis to have an important influence; it is that some cars require greater directive effort than others. In other words, due to the location of the center of gravity with reference to the front wheels, skidding is more prevalent where the center of gravity sets well forward along the wheelbase, and it would be perfectly possible to cause a front-wheel skid without brakes in any car by giving the steering-wheel a very sudden wrench; but the car that will skid most easily will be the one having its center of gravity farthest forward

Regarding internal versus external brakes, the internal-expanding brakes are from all points of view unquestionably the most desirable and logical type of brake to use on the front wheels. The designs can generally be made neater in appearance, and the controls more easily and simply arranged. Due to elastic conditions of the front-axle system and its mounting with front springs and steering, automatic servo-characteristics such as those obtained with external brakes are undesirable because of the liability to danger. The self-compensating action of internal brakes, due to expansion during long braking periods, is a feature of extremely great merit. When it comes to rear brakes, however, the problem is somewhat different. If an entirely separate set of emergency brakes is to be provided, either to comply with legal requirements or as an added safety feature, a propeller-shaft brake must be supplied or else external-contracting brakes may be fitted to the rear axle. The many objections to propeller-shaft brakes are well known; hence, the general tendency and the most logical thing to do is to supply two sets of brakes on the rear axle. If both sets are fitted, it is optional with the maker whether he shall use the internal or the external brakes for service. The preference is to use external brakes for service, and it can hardly be denied that taking advantage of the self-acting principle of the external brakes is a sensible thing to do.

M. PERROT:—Even if you have an equalizer on the front-wheel brake, a portion of the weight is transferred from the inside to the outside when you are taking a curve and, if the brakes are applied equally to those two wheels, you will lock the inside before you will lock the outside wheel. The only thing wrong with the front-wheel brake, as I explained before, was that it was easy to lock the front wheel when taking a curve and to cause

a skid, but I have had no trouble with my application. When rounding a curve, if you lock only one of the front wheels, you will not lose your steering.

Concerning internal and external-brake applications, I think a system must be evolved such that one can check a car under any conditions by either the hand lever or the foot lever. The layout must be in such shape that, if any of the parts wear-out, there will be something to take their place.

T. J. LITLE, JR.:—I think that when we have read M. Perrot's paper carefully, most of us will agree with him. Pedal pressure is important, whether you use two-wheel or four-wheel brakes; it should not be excessive. In the case of some of the internal brakes used at present, entirely too much pedal-pressure is necessary to operate them; consequently, their design must be changed.

The principle of application used on some of the internal brakes is very much like the old-fashioned brake on the wagon wheel that was simply pushed against the wheel. M. Perrot says that an internal brake should be self-energizing. That is a very important point with respect to reducing the pedal pressure needed. Of course, we do not want a brake to grab and take the car out of our control. On the other hand, we do not think it is a good thing to be forced to resort to some other means, such as servo-mechanisms, to operate brakes. We would rather operate them in a direct way.

W. R. GRISWOLD:—In connection with releasing the outside front-brake of a car when rounding a curve, so long as American designers insist on having a greater portion of the braking effort applied to the rear wheels, just so long will it be unnecessary and no contribution to safety to release the outside wheel.

M. PERROT:—I have looked at all types of American-four-wheel brake, and my opinion is that you do not yet take the full advantage of the front-wheel brakes. You are afraid to do so, and I believe you are right. You are trying to make the proposition safe for the public. That is a very good point, but I am absolutely certain you will get more out of your front-wheel brakes eventually than you do now; then you may find the release feature a good thing.

B. B. BACHMAN:—What are the relative characteristics of the internal brake M. Perrot described when operating in the forward and in the rearward direction?

M. PERROT:—The brakes I have described can be made to act both ways, but we find that absolutely unnecessary in the case of front brakes.

W. W. TUTTLE:—In rounding a curve, an axle transfer of weight from the inside front-wheel to the outside front-wheel takes place. Why is it logical to decrease the braking effort on the outside front-wheel when you have already added to the percentage of weight carried by that wheel? That does not consider any added ease of steering that may be accomplished by doing this.

M. PERROT:—I discovered that by experiment. Our braking system is such that we can brake either the outside or the inside wheel, we can brake the two wheels the same amount, or we can brake the outside wheel more than the inside wheel. Experience teaches me that braking the inside wheel is the best.

MR. JACK:—What proportions of the total braking-force do you recommend for the front and for the rear wheels?

M. PERROT:—On touring cars in Europe at present, 50 per cent front and 50 per cent rear. On a racing car, where you do not need to stop the car but only to slow-down, we use about 65 per cent on the front and 35 per cent on the rear.

HERBERT CHASE:—M. Perrot has distinctly favored the inclined knuckle-pivot. At least one car designed in this Country employs a vertical knuckle-pivot, the axis of which intersects the road a considerable distance from the center of the tire contact with the road. Will some advocates of that arrangement state why it is used in preference to the design favored by M. Perrot?

M. PERROT:—In that case, when the brakes are equally good, there is no trouble; but, with that type of steering it is impossible to apply the brake on one wheel alone. I think that you must be able to apply the brake on only one wheel and be absolutely certain of your steering.

O. M. BURKHARDT:—The Pierce-Arrow company has decided to use a vertical spindle for the reason that we had difficulties from "road fight" in the case of center-point steering. The retarding forces of both wheels are about the same; so, under almost all circumstances, we have equal and opposite forces that are balanced through the tie-rod. We have found that, in case one wheel becomes locked on slippery ground and the other rolls on dry pavement, our nearly self-locking steering-gear, with a ratio of 15 to 1, helps to counteract the unbalanced forces. Clearances in our steer-linkage are very small, so there can be no response on the steering-wheel to what is going on at the road wheels.

In connection with M. Perrot's self-energizing brake, what influence has the coefficient of friction on this? W. S. James has shown us that the coefficient of friction fluctuates considerably. Suppose we have a high coefficient of friction on one wheel and a low coefficient of friction on the other; there is a possibility with a self-energizing brake of tracking to the left or to the right, even with nearly center-point steering, because of the considerable increase in brake ability due to the wrapping.

M. PERROT:—That effect is the same with any kind of brake. The zig-zags shown on the retardation curves are not absolutely due to the effect of the brakes. I think they are due to spring-suspension more than anything else. I believe Mr. James will agree with me on that. There is more work to be done on springs and on steering-systems than on the brakes. The brake problem must be worked-out with these other problems.

CHAIRMAN W. R. STRICKLAND:—In connection with the external versus internal-brake arguments, we found at the Cadillac plant that, with internal brakes, the pedal throw was great and you would strike bottom; whereas, with external brakes, on account of the expansion of the drums, the brake clearance was quickly taken-up and the brakes would drag or seize. We adopted the internal brake on the front wheels to secure cleanness of design and protection of the most sensitive brake-linings, and the external brake on the rear, thereby getting a heat balance between the two. We are able to operate the brakes with a small clearance and still have none of the above-mentioned troubles, with a minimum travel of the brake-pedal, when the brake-drums expand with the heat.

As the braking effect of the rear brakes is purposely greater than that of the front brakes, the expansion of the drums is greater and, with the brakes applied and heat being generated, the tightening of the brake-rods from the rear is slightly greater than the loosening effect from the front; so, the resultant movement of the brake-pedal is slightly backward, or in the safe direction to assure stopping with brakes.

When steering to turn a corner or miss an obstruction, the releasing of the outer front-brake of a four-wheel-brake installation increases the driver's ability to control his car. Proper control of a car signifies the ability

always to steer it where one wishes to go or to swing the front end of the car away from a collision-point to avoid accident. A large number of head-on collisions are avoided on account of this ability with two rear-wheel brakes, even though the wheels are locked and there is skidding at the same time. Equal control for the avoidance of collisions can be maintained and the possibility of collisions greatly reduced with four-wheel brakes by causing one front wheel to roll and thus provide steering by using the releasing feature on one front-wheel brake when the wheels are thrown to either side. Furthermore, when unexpected sharp turns having obstructions are encountered while touring, and this applies whether on wet or on dry pavement when the speed is proportionately high, the locking of all four wheels, which the driver does instinctively, would hurl him into the abyss or the obstruction if the releasing feature, working automatically, did not give him a response to his steering endeavor to keep the road or miss the obstruction. While very moderate driving at all times diminishes the danger factor, the number of collisions and accidents that occur daily attest the necessity for adopting every safety factor possible. That the releasing of the outer front-wheel accomplishes the purpose can be demonstrated easily without placing oneself in any danger, by trying it on an open slippery road at a road intersection. The driver should be able to throw the front end of the car in either direction that he may wish to go, after applying the brakes vigorously.

The proper handling of two-rear-wheel-brake cars is known to most drivers. One of the points the driver acquires or is taught is how to retain control of the car when skidding around a corner, due to speed or rear-brake application, or righting the car when a rear skid begins, by steering the front end in the proper direction. So far as I know, no satisfactory way of correcting a front-wheel skid exists. Releasing the brakes, which cause the front-wheel skid, so as to secure steerage as advocated by some persons, is like asking a drowning man to let go a rope. But, assuming that an experienced driver will release the brakes as advised, he releases at the same time all retarding effect of the brakes and increases the difficulty of making the turn.

The response to steering, when the outside front-wheel automatically rotates when making a difficult turn on slippery or dry pavements, is absolutely dependable. It may be claimed that, with the inside front-wheel locked and skidding and the outside wheel just beginning to rotate and consequently not yet freely released from the braking effect, a rotating couple, tending to throw the front end to the outside, is produced. This effect is always less than that of the inside wheel and is more than counteracted by the transverse friction of the tire on the pavement which causes the wheel to turn, up to a 45-deg. cramp, with a greater force than the force producing the couple. The controversy is entirely wiped out when all braking on the outside wheel is removed and the road resistance turns the wheel and the front end of the car in the desired direction.

The advantages of the releasing feature are that, after the impulsive attempt to stop and at the same time avoid the trouble or make the turn, you are going in the direction your instinct told you to attempt to do. Whereas, without the release and steerage ability and with all four wheels skidding, you will crash or go off the road. It has been argued that releasing one wheel reduces the braking effect, but the fact that the front end has been turned shows that the front end of the vehicle has been retarded faster than the rear in the direction of original motion, and the road space vacated by the front of the vehicle provides several additional feet of rear-wheel travel for the remaining brakes to cause the car to come to a stop before the fender and wheel strike the obstacle.

These conditions were developed with mechanically equalized and with hydraulically equalized four-wheel-brake cars, and afterward they were obviated by the use of the releasing feature of the outside front-brake; and by limiting the proportion of the total braking which goes to the front-wheel brakes to such a point that skidding on the front wheels occurs only after the rear wheels have skidded, whether on dry or on wet pavement. It should be noted in this connection that, on slippery pavements, when very little pressure is required to lock the wheels, the shifting of the weight of the vehicle from the rear to the front, due to the retarding effect, is almost nil; and so is the friction on the slippery surface. On this account, it is desirable to determine the relation of braking effect for the front and the rear under slippery conditions, without taking the shifting of weight into consideration. Consequently, the maximum possible braking on dry pavement which takes advantage of the shifting of weight to the front cannot be utilized without first locking and skidding the rear wheels and bringing into play the additional pressure required for the front.

A. Y. DODGE[2]:—In answering Mr. Vincent and Mr. Griswold, first let me make known the following facts. We relieve our outside wheel; we do not release it. On a full lock, we still have approximately 50 per cent as much braking in the outside front-brake as we had going straight ahead. The inside brake is tightened only about 10 per cent, in spite of the fact that the inner wheel turns through a greater angle than does the outside wheel. This sounds peculiar, but I wish to assure you that it is true, and that you can find many peculiar things if you analyze the kinematics of a universal-joint set above an inclined knuckle-pin, and their combined movements. Various combinations can be secured.

Another fact is that no car goes around the shortest turn it can make at a fast rate of speed. If you wish to consider the more gradual turns, you will find we relieve the front wheel proportionately less. We do this to reduce front-wheel skids and not to reduce rear-wheel skids. We wish particularly to prevent front-wheel skids in very slippery weather; but we are little concerned about rear-wheel skids any more.

A four-wheel-brake car is very much more immune to rear-wheel skids than is a two-wheel-brake car. This immunity exists to a large extent even in cars that still do heavier braking in the rear. I am very much surprised to hear Mr. Vincent or Mr. Griswold speak of a rear-wheel skid as more serious than a front-wheel skid. I feel that every person who has driven 10,000 miles or more knows considerable about handling a rear-wheel skid. On the other hand, I am very well acquainted with some expert drivers and I have failed to find any one who knows much about rectifying a front-wheel skid. I will admit that a rear-wheel skid looks bad on a diagram when you are studying the forces and the couples because, on the diagram, the magnitude of the couple increases rapidly as the angle increases provided the skid is permitted to go on.

I have studied force diagrams and the kinematics of an automobile rounding a curve, skidding and going straight, and have found the use of a small model to

[2] M.S.A.E.—Chief engineer, Perrot Brake Corporation, South Bend, Ind.

check and guide me in my deductions very helpful. The forces that act on a car when going around a curve are, of course, dependent on a number of variables; but, in all the cases that I have figured out, I find the couple caused by relieving the front brake the way we do it to be very small compared with the other forces, acting on the car at the time, which tend to cause a rear-wheel skid. Mr. Griswold will find this force to be very small if he will use in his figuring the proportions of compensating that we recommend. Also, he will see wherein the aid to steering received thereby is justified; and he may even recognize it as a source of safety, making it advisable to utilize additional braking in front for the best results, all types of skids considered.

THE THEORY AND ADVANTAGES OF BALANCED BRAKE-FORCES

BY GEORGE L. SMITH

DESCRIBING first the two methods of brake application in use in the United States, the theory of balanced brake-forces is then propounded by the author, who compares the methods and comments upon them. Illustrations are presented and used to analyze the brake forces, and practical applications of an equalizing mechanism used in road tests of an automobile are stated and considered in some detail.

Tests on wet pavements were made and skidding was studied, the skid-checking effects being noted and explained. Additional tests were made on hills, and the results of these are included, together with a presentation of the effects of speed and pressure. Wear on the tires and on the brake-lining, the effect on steering ability, the advantages of an automatic signal that brake-adjustment is needed and the measurement of individual brake-force are the other subjects discussed. [Printed in the February, 1924, issue of THE JOURNAL.]

THE DISCUSSION

D. M. PIERSON:—Through what variations of friction coefficient would the device operate before reaching the limits of its ability?

G. L. SMITH:—That depends to a great extent upon the design of the mechanism. It can be made very effective or it can be made sluggish. The amount of rotation to effect a certain change in pressure depends upon the leverage of the compensating link around the axle center. If the link passed through the axle center, practically no change of pressure would result from rotation of the bands. The greater the lever arm is the quicker the response will be and the less will be the rotation of the bands required to produce a variation in pressure. Compressibility of the brake-lining also reduces the sensitiveness of the mechanism since a greater movement of the brake levers is required to effect an increase in the pressure. Torsion in the operating connections between the foot-pedal and the right and the left brake-levers likewise reduces the range of equalization. In this case care must be exercised to make these connections such that the torsional loss on one side will not be more than on the other. Failure to do this causes the rear end of the car to creep toward the weaker side when the brakes are applied hard. This torsional loss should also be reduced to the minimum.

The first car that was rigged with this device had a lever arm for the compensating link of about 4 in. This link was very short and the position of the rear end of the link was well forward of the axle center. As the link would swing up to effect an increase of pressure, the lever arm would shorten and as it would swing down to effect a decrease of pressure, the lever arm would lengthen. In this way the turning-moment of the thrust of the link remains approximately a constant and does not detract from accurate equalization.

In fixing the limits of this mechanism, we first designed the rigging to give a throw of the anchor stud up or down of $\frac{3}{8}$ in. on a 14-in. brake-drum. After about a 2-year test of this mechanism, we never have found a condition where this movement would not handle the variations in the coefficient of friction. The dimensions of this rigging were such that one could tighten on one band three turns of the adjusting nut and slack three turns on the other side, and this would just about throw the equalized rod from one side to the other. That change of adjustment meant about a 0.12-in. take-up of the band on one side and a 0.12-in. slack-off on the other, which is very extensive. The leverage of this first brake system was not great, although one could push hard enough on the foot-pedal to lock both wheels when using a good grade of brake-lining. With the brake-lining oiled or wet, sometimes it would be very difficult to lock either wheel; but the throw of the system in nearly every case could be made to care for a variation in the coefficient of friction corresponding to that where the high value was three times the low value.

J. H. HUNT:—A statement was made that, if one wheel locks, the braking effort on the other wheel is reduced. If one wheel were on ice, what percentage of the braking effort would be taken from the other?

MR. SMITH:—The question carries the subject from the brake down to the road. We cannot entirely overcome the bad effects of a tire on slippery places such as greasy pavement, ice or snow but, under those conditions, the mechanism will slack-up the pressure on the opposite side until movement is arrested by the limit stops.

CHAIRMAN W. R. STRICKLAND:—Taking the variation in the coefficient of friction between the two wheels, what percentage of loss of braking would one get on the side having a high coefficient? Undoubtedly the braking force on the high-coefficient side is reduced because, as the low-coefficient side receives more of the braking power, it must come off the other side in case there is no equalizer. In the case where Mr. Smith speaks of 100-per cent reduction in the coefficient on one side, not much braking effort could be obtained on the other side.

MR. SMITH:—Such a calculation is very simple. When the coefficient of friction is the same on each brake, the conditions are such as to give the maximum braking-effect. As the coefficient on the right side picks-up and the coefficient on the left side drops, for instance, naturally the pressure is distributed more to the low side and taken off the high side to produce a balance. Carried far enough, a very extensive loss in the total braking-power would occur and limits stops are necessary for

this reason. If both coefficients are the same, the total braking-force is greater than would be the case if one were high and the other low. That can be figured mathematically, and it must be expected. The answer we give to that question is this: It is better to have moderate braking-power with safety, than high braking-power that may land one in the ditch. We have had several cars running in actual service, about 3 years for the oldest one, and tests show that the coefficient of friction does not vary appreciably. It remains more nearly a constant because the work and the heating action are necessarily the same on each side. The automatic balancing action, going on even while the brake is being applied, tends to keep the heating and the wearing effect the same. The result is that the coefficient of friction does not get very high on one side and very low on the other. Running with this rigging for a day's run of from 250 to 300 miles through dust and mud, we find that the brakes work about the same at the end of the run as they did at the beginning, instead of slacking-up and getting very weak, as was especially true with this identical machine before this rigging was applied.

W. E. LAY:—When water was put on one brake-drum, did you find out what the reduction of the actual coefficient of the brake-band was?

MR. SMITH:—The charts I showed were copies from actual tests but the data were never worked out for absolute values. The decelerometer will not show anything but the mean figures; it will not discriminate between the right and the left brake. Seemingly, the actual effect of wetting one brake, so far as the appearance of the chart is concerned, is to give it a rise; it starts low and then picks-up and, at the end, appears to be as high and sometimes higher than it was without the brake being wet.

QUESTION:—Were the cars that were used in the test run with the linkages well lubricated or was no attention paid to lubrication?

MR. SMITH:—No attention was paid to lubrication when the curves were obtained. We have made tests under all conditions. On the cars that I have driven, I have intentionally neglected them for long periods of time. I made the first rigging myself to test the principles involved and no consideration was given to length of service. I did not expect to have it last more than a month or so to give me an opportunity to find out what the situation was; to see where troubles developed and to remedy them. My idea was then to build a proper set and test it for endurance. As a matter of fact, this first rigging was built of bell-cranks of 3/16-in. sheet metal with bell-crank pivots of ordinary ½-in. bolts and the other pivots ⅜-in. pins; but the rigging is still on the car and is working satisfactorily. This indicates that no great accuracy in workmanship or fitting of parts is required.

The pull on the equalizing mechanism that anchors the brakes is very considerable and the sticking of a pivot really does not have much effect on it. If it sticks, it will give. Any appreciable unbalanced action will develop a force sufficient to start it moving and, if it once starts moving, it will free itself. The only case in which we have had a sticking pivot was that of a bell-crank, for which we provided lubrication. It should be lubricated the same as a spring-shackle bolt, but the operator of this car paid no attention to it until finally it stuck and would not work. As soon as it was freed, the mechanism worked satisfactorily. The only effect of a frozen pivot is to eliminate the action of the mechanism and cause the brakes to operate the same as standard types.

H. A. HUEBOTTER:—Is it possible to modify this system and make it apply to the rigid type of brakeshoe such as is used for internal braking?

MR. SMITH:—We have never found a brake system that we could not modify to embody this principle of braking equalization. The external brake is the simplest. In fact, the brake itself is simple and the putting on of the additional parts in the rear is very simple. We have various plans that we have submitted to different companies showing what can be done for an internal brake. Designs have been drawn up for a cam-operated brake, but it is a more expensive proposition. It means a more extensive change such as a redesigning of the mechanism; whereas, in the external type, many of the cars that are now running on the streets can be modified with very little trouble and expense. The external brake is generally conceded to be the simplest, cheapest and most powerful when working up to its maximum efficiency and our differential insures its working up to its maximum efficiency, commensurate with safety.

O. M. BURKHARDT:—I am fully convinced that the mechanism lends itself admirably to compensating for the coefficient of friction; but changes are taking place in the retarding force which may be caused by out-of-round drums and the like. We have a rather sudden change there. I wonder if flexibly anchoring the brake-bands will not accentuate the trouble that we have with band brakes chattering and gripping and that results in the disagreeable phenomenon of the wheel leaving the ground. In this connection the analysis of the forces in the linkages due to a change of friction from one side relative to the other would be most valuable. Suppose one brake is frozen; it is very hard to loosen this brake. We have to rock backward and forward. In this case of the frozen brake, the other brake will be applied twice as hard. That can scarcely be avoided. Adding more linkage naturally brings about a condition that makes the brake more responsive and again militates against close adjustment.

MR. SMITH:—In regard to grabbing of the brakes, the equalizing mechanism at the back allows a very slight rotary action of the band before the force begins to build-up. Consequently, no tendency to grab is present. I have adjusted the brake-bands so tight that there was practically no clearance and have had no trouble with grabbing brakes. Occasionally, if a brake should drag too hard, the latch would unlatch and one would probably hear a clicking sound, but it could not cause any injurious effect because one brake cannot grab unless the other does also. In other words, it is a tug of war between the two. So far as locking and chattering are concerned, the brake levers have to point up to effect equalization and that is also the desirable position to avoid chattering brakes. As to the matter of rattling brakes, we have made tests to show that noise and rattling do not exist with properly designed parts. At only one time have I ever found any such action; that was on our first test-car and was caused by the pivots becoming loose. Tests made at the Bureau of Standards on the same make of car, with and without the differential, show curves much more steady with the differential installed. Vibration of the recording pen was about one-third of that obtained with standard brakes. The slight chattering and grabbing that has been noted has always been experienced in backing. It stands to reason that chattering of the axle would be reduced, since the torque is the same on each side. We have discovered also that the differential reduces and usually eliminates squeaky brakes.

Trimming Materials and Style

By H. T. Strong[1]

Annual Meeting Paper *Illustrated with* Photographs

WOOL is the short-staple fiber taken from the fleece of a sheep; worsted is the long wiry fiber combed out of the wool and put through a different process of spinning; all mohair comes from the long-haired Angora goat. Formerly every man wore woolen clothing; now he wears worsted, because it wears better, does not hold the dust and stays in shape better. Worsted has been largely adopted for automobile upholstery for the same reasons, and because it has a resale value not surpassed by any other material.

So great a degree of perfection having been reached in mechanical construction and in the beauty of the exterior lines of present-day cars, more attention, in the opinion of the author, should be devoted to beautifying their interiors. The pendulum having swung from the extremely garish and ornate to excessive plainness, the question is asked whether the time for the return-swing has not come, for sales reasons that are realized by other industries; and suggestions are offered regarding improvements that might be made.

The fallacy of buying low-grade carpets is shown, a saving of $1 per yd. sometimes causing an expenditure of $10 for new carpet within 2 or 3 months, whereas the better carpet would have lasted 2 years. Brussels horse-hair carpet is often purchased for phaetons and velvet or Wilton weave for closed-car work.

When buying carpets the count of the sample should be inspected. This can be done readily by a counting-glass. A quotation honestly submitted on a sample of carpet should be accepted; for if the price is forced down it is likely that reworked wool, or shoddy, will be used that will give a poor wearing surface, although the difference will not be apparent until the carpet is put into use.

In curtain silk, on the other hand, the substitution of fine Sea Island cotton for silk will increase the wear; in very low-priced cars mercerized all-cotton fabric is preferable. Perfect all-silk fabrics are difficult to secure, because of the fact that the strands, which usually consist of eight filaments, sometimes contain nine, sometimes only six or seven, and also because the filaments from healthy cocoons are a little larger than those from cocoons not so healthy. For medium-priced owner-driven cars of the sedan or coupé type hard-wearing durable dark-colored fabrics are recommended, while for the more expensive types face-finished broadcloths or soft suede, or velure-finished woolen fabrics of lighter and more artistic colorings, are to be preferred. More attention should be given to instructing salesmen regarding the reasons for selecting particular fabrics.

As only 2 per cent of the selling price of a car is expended for upholstering materials, and as the final decision as to the selection of a car is usually left to women, it is important that the impression made when the car door is first opened should carry an appeal for ownership.

Care should be taken to see that fabrics maintain the quality of the sample. Various devices are described by which this may be done quickly. These include an improved hand-operated cloth-tester for determining the warp strength and the filling strength, a cloth-sampling scale by which the weight per running yard can be ascertained simply by weighing a small sample, a Fade-Ometer for determining the quality of the dyes, a counting-glass for counting the number of threads in all kinds of fabric, a boiling-out outfit for testing the proportions of wool and cotton in the material and daylight lamps for examining the color and finish.

IT is said that when a man begins to reminisce, it is a sign of old age. That may be so, and I shall do only enough reminiscing to form the basis for a talk on closed-car interiors. It was 21 years ago this month that the Quinby company of Newark sent me to Europe to study the methods employed by foreign body-builders in developing the aluminum automobile body. I visited the factories of Rothschild, Kellner, Labourdette, Muehlbacker and others, and spent considerable time in each plant, learning the mode of framing-up the woodwork, forming and attaching the aluminum panels, and studying the art of interior upholstering and the preparing of the aluminum panels for painting. After 5 weeks of this intensive study, Presto, chango! I popped out of the hat a full-fledged body engineer, very anxious to become a member of the Body Division of the Society, but I found that I antedated its birth by 18 years.

You engineers may think that you have problems to contend with today, but really they are negative. At that time, we annealed aluminum panels with a blow-torch until they were as soft as putty. We then beat them out by hand with a mallet to obtain the proper shape; but we could find no way to harden the panels again, and the first time someone leaned up against them or tried to push the car, he left a deep imprint in the panel. It was necessary then to remove the upholstery and beat the panel back into shape, which was done repeatedly. This course was pursued for several years until the introduction of the power-hammer, which made it possible to beat the panel out cold.

I remember distinctly the first cabriolet-type body we delivered. The entire back broke off and fell into the street on the first bump the car went over. And I also recall the first two limousines sold to one of the most important manufacturers of today. The chassis were constructed in such a way that when the owner drove from the showroom in West 59th Street into Central Park, the driving-shafts fell out of both the chassis because the bodies were so heavy. The cars had to be taken back to Newark, the bodies removed and the chassis rebuilt to stand the added weight of the closed bodies.

The first enclosed car I sold was on a 180-cm. (70.86-in.) chassis. This body had a back entrance and seated two persons in the rear compartment. Shortly thereafter, we conceived the brilliant idea of a front door at the side of the driver's seat. This was long before a side-door body was thought of.

These first cars were upholstered in either goatskins or broadcloth, in blue, green and maroon coach-colors, which created a very somber interior. From these very dark colors, the pendulum of fancy swung to an extreme of light colored, plain and striped, imported and domestic woolen cloths. It was impossible to keep them clean, and some were so poorly made that they had very little wearing quality. These continued in vogue until about

[1] William Wiese & Co., Inc., New York City.

5 years ago, when the demand for touring cars, as they were then known, began to decrease and closed cars became more popular. The builder turned to darker and more serviceable woolen cloths and mohair velvets that would increase the resale value of the cars, for the cost of reupholstering closed bodies had more than doubled during this time.

Wool, Worsted and Mohair

The question is often asked, "What is wool, what is worsted, and what is mohair?" Wool is the short-staple fiber taken from the fleece of a sheep, worsted is the long wiry fiber combed out of the wool and put through a different process of spinning; while all genuine mohair comes from the long-haired Angora goat.

Ten years ago nearly every man was wearing woolen clothing. Today nearly everyone is wearing worsted. Worsted wears better, does not hold the dust and stays in shape better. For these reasons, many experiments were made with worsted fabrics for automobile upholstery, and a great step forward has been made in adopting them, especially for the sedan and coupé types of owner-driven car.

When a sheep is sheared, the fleece is taken off almost intact, and when it is spread out on a table, it resumes the same shape it had on the hide of the animal. Several major selections of wool and worsted are taken from the fleece of a sheep. Some fibers, as I have said, are short and fine, and are made into the yarns from which woolen cloths are woven; others are long and wiry; these are combed out and spun into worsted yarns. Long closely-spun worsted yarns offer more resistance to wear than short soft-fiber woolen yarns. We believe that eventually the real upholstering cloth for the owner-driven type of car will be made of worsted fiber. It is cool and pleasant to ride upon, will not hold dust and dirt and, because of its wearing quality, has a resale value that is not surpassed by any other material.

The modern closed-car has reached so high a degree of perfection of mechanical construction and beauty of exterior line that builders today feel like the tooth-paste maker who says: "We could not improve the paste, so we improved the box." I ask the question, "Have we developed the interior of our cars to the same extent that we have the mechanical part and the exterior?"

I believe that everything in this life moves in cycles. Although a few years ago the most expensive cars were so garish and ornate that more than 18 yd. of broad lace was used in a single car, the change came soon after that to plain upholstery. This cycle of extreme plainness having now covered a period of several years, customers and builders alike are wondering whether it is not time for a change to more elaborately decorated interiors. There is a sales reason for this, which all other branches of industry have realized.

If a person goes into a showroom and sees a car that looks, so far as interiors go, like the car that he bought 2 or 3 years ago, he has no desire to make a change; there are no outstanding features that label his old car out-of-date. For this reason, it seems to me that changing the interior upholstery every few years would create a better selling condition.

Plain upholstery has certainly had its day, and an effort should be made at once to change the appearance of the interiors of the better grades of car. One of the best ways to bring back a more ornate interior is to use broad lace in the most expensive cars, semi-broad lace in the moderate-priced cars and decorative pasting lace and plain seaming-lace.

By using figured material for the cushions, backs and arm-rests, a plain headlining and broad lace on the doors, which could be trimmed with the headlining material, a very interesting combination of cloth can be made, a better grade of material can be used in the wearing parts of the car and a much less expensive and lighter-weight cloth in the rest of the car, as the thinner material is all put on flat and gets very little wear-and-tear.

Carpet

Without question, it is the aim of automotive engineers to give value received for every dollar expended, and in most instances they succeed. But the material that gets the rawest deal is the carpet. In your own home, you take the most pride in your floor-covering. You will buy quality for your home, and then for the 2 or 3 yd. of carpet that goes into a $2,000 to $4,000 car you will buy on a price basis only, by setting a certain limit per yard on what you will pay for a carpet, thereby turning down $10 worth of service to save, perhaps, $1 per yd. No part of the interior of a closed car has to stand the grinding wear that the carpet does, and the weave makes it impossible to manufacture cheap carpets, the face of which will not pull out in 2 or 3 months. It is then necessary to spend $10 for new carpet, whereas a dollar or so added to the original purchase price would have bought a carpet that would have lasted 2 years.

Brussels horse-hair carpet is often purchased for phaetons and velvet or Wilton weave for closed-car work. Both types of carpet are woven over wires and a mechanical hand everlastingly pulls out the back wire and carries it forward between the warp threads at each throw of the shuttle. A plain wire is used for the Brussels weave, and a wire with a knife on the end of it for the velvet weave, so that every time the knife is pulled out, it cuts the loop. This makes the velvet or Wilton weave.

Medium and high-priced carpets are all made from either woolen or worsted stock. The fiber of wool, being shorter than that of worsted, is likely to pull out, whereas the worsted fiber can be tied in tighter. The face of a worsted carpet will therefore wear longer and stand harder service. Worsted, too, is more dust-repellent than wool.

Inspection

When you buy a carpet, find out the count of the sample submitted. Use a counting-glass to count the ends, that is, the warp threads across the width of the carpet. If you buy a 9-wire, 240-pitch carpet, there will be nine cut loops running lengthwise of the carpet per inch, and there will be 240 warp threads across the width of a 27-in. carpet, not a 36-in. width. The way to measure the standard of the carpet is to count 3 in. across and multiply by nine. You will then have the exact count. It will be necessary to watch the height of the pile or face of the carpet to see that too small wires are not used, which would give a lower pile and cheapen the carpet.

An honest carpet salesman quotes you a price on a sample of carpet made of virgin wool. When you begin to put the screws on him to get his price down, he looks round to see where he can put in some reworked wool, which is known as shoddy and is nothing but old materials teazled up and used over again. This gives a very poor wearing surface that is not detected until the carpet is in use. So, just remember that when some honest carpet manufacturer gives you his lowest price on carpet, a reduction in that price will certainly be paid

for at a dear price by the eventual owner of the car, and this, after all, reflects on the automobile builder, as it is almost impossible for anyone except an expert to detect the debasing of carpet with reworked or second-hand raw material.

Curtain Silk

Curtain silk presents a condition entirely different from that of carpet. By substituting fine Sea Island cotton for silk in the filling of the material, a strong silk can be made for medium low-priced cars that will probably give more wear than all-silk. For a very low-priced closed car, I much prefer a mercerized all-cotton fabric at about 35 to 40 cents per yd. to a silk-warp cotton-filled material at twice this cost.

It is practically impossible to weave a perfect piece of all-silk fabric. The fiber that is used in automobile silk

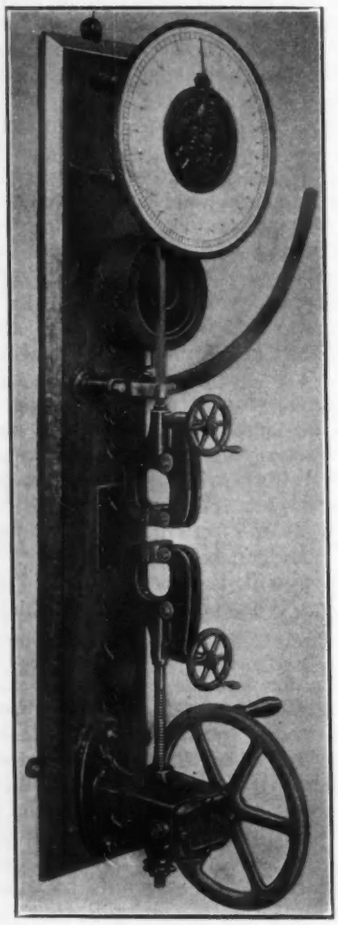

Fig. 1 — Hand-Operated Cloth Testing-Machine To Determine the Strength of the Warp and the Filler in a Piece of Fabric

To Test the Breaking Strength of the Warp Threads in a Piece of Cloth, the Fabric Is Clamped in Place and Tension Applied to the Warp Threads until They Break, the Exact Number of Pounds Pull at Which the Break Occurred Being Registered on the Dial at the Top. The Same Procedure Is Followed for the Weft or Filling Threads, the Fabric in This Case Being Clamped So That These Threads Run Vertically

is reeled from cocoons, an average of ¼ mile of filament being unwound from each cocoon. The average unit of

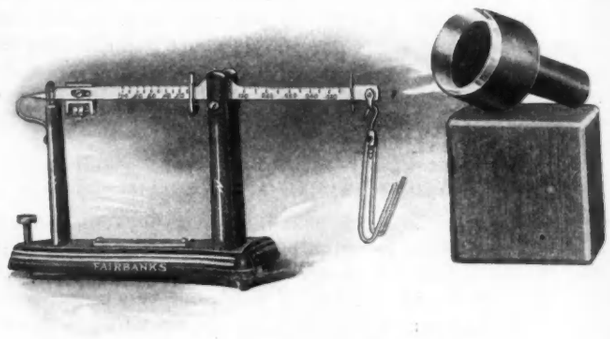

Fig. 2—Cloth Sampling Scale

This Outfit Determines the Weight per Running Yard of Any Cloth Simply by Weighing a Small Sample. The Cloth Is Placed on the Wooden Block and a Sample Having an Area of 4 Sq. In. Is Stamped Out by the Steel Die. This Sample Is then Placed in the Fork at the End of the Scale Beam and the Latter Is Balanced. The Indication on the Beam in Ounces Multiplied by the Width of the Cloth in Inches Gives the Weight per Running Yard

fine thread is composed of eight of these filaments, eight cocoons being unwound at a time. Machinery is now used to some extent in unreeling the cocoons, but until recently almost all silk was unreeled by boys and girls, who stood in front of small basins filled with hot soapy water in which were placed 10 cocoons. These children had to find the ends of the strands, throw eight of them over a drum, and two over the edge of the basin; the drum was then started, and the cocoons, unwinding, would bob up and down in the water, assistance being given by something resembling a whisk-broom, with which the cocoons were tapped. When a cocoon stopped bobbing, it was an indication that the filament had broken, and one of the cocoons, the end of which was lying over the basin, was immediately thrown over the drum and filled in to make the eight. It was then necessary to find the broken end of the other cocoon and have that ready when another break occurred. You can see that it would be impossible to have all these initial threads of the same size, as sometimes nine filaments might be running at one time, and sometimes only six or seven. That is the reason we find bars in all curtain-silk. Not only is it impossible always to have the same number of filaments in the initial threads, but some cocoons are larger and healthier than others, and the eight filaments from healthy cocoons give a little larger thread than those from other cocoons that are not in so healthy a condition. So, please be just a little more considerate in returning silk that is not, to your mind, perfect.

A condition has rapidly developed in the last few years that is putting the phaeton in the class with the dodo bird and the dinosaur, extinct species. The sedan and coupé types of car are only evolutions from the phaeton and have created a demand for a type of car entirely different from the original limousines; so we suggest that, for the owner-driven car of medium price, you select hard-wearing durable dark-colored fabrics, while for the more expensive owner-driven or chauffeur-driven types of car you select face-finished broadcloths or soft suède or velure-finished woolen fabrics of lighter and more artistic colorings.

Education of Salesmen

Not enough attention is given to educating the salesman who is on the firing-line, regarding the quality of the fabrics used in the interiors of closed cars. I would suggest that when the material is changed, a card be

printed and placed on the steering-wheel of every new car going on the showroom floor and that the card have printed on it a description of the fabric with which the car is upholstered, telling of the good wearing qualities, the fastness of the dyestuffs and why it has been selected for use in that particular type of car.

Shortly after one of the large companies in this Country had changed from a woolen to a worsted cloth, I talked with the salesmen at the different automobile shows of many of the larger cities and did not find in a single instance that any information had been given the sales department regarding the new fabrics used. This is a subject that should have more consideration.

If I were to ask you engineers what proportion of the selling price of the car is spent for the interior upholstering materials, such as cloth, carpet, silk and passementerie, I believe that not one of you, without figuring it out, would give a sufficiently low estimate. Only about 2 per cent of the selling price of the car is expended for the upholstering materials, whereas no part of the automobile creates so great a desire for ownership as the interior upholstery. I believe that when you realize this, you will endeavor to see how you can build up, rather than tear down, the interior attractiveness of the car.

We must realize that the final decision as to the selection of a car is left to women and, in the majority of cases, the time at which the sale is made or lost is when the salesman opens the door of the car and the prospective buyer looks into the interior. At this psychological instant there must be an appeal for ownership.

We are at present going through so hectic and competitive a period in the evolution of the automobile business that we sometimes forget some of the basic and fundamental business principles. I believe it will be necessary to inject a hypodermic of common-sense into the epidermis of the "powers that be," who are now demanding price and price only to the exclusion of honest value, and I think it is up to you body engineers to maintain a certain standard of quality, for you are aware that a gold dollar is never bought for 50 cents!

A halo of romance hovers over the interior of modern closed-cars. Do you know that the raw materials used in the manufacture of the cloth come from Australia,

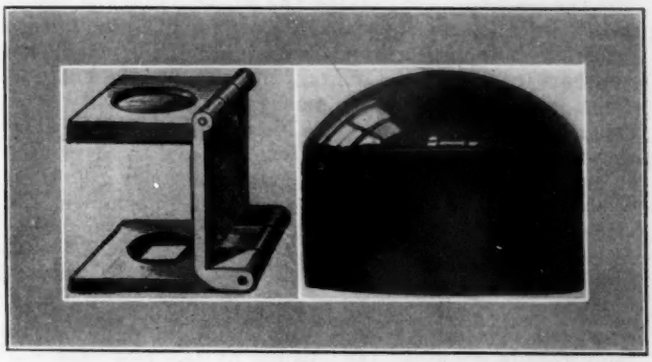

FIG. 4—TWO GLASSES USED IN THE EXAMINATION OF FABRICS TO SEE IF THEY CONFORM TO THE SAMPLES SUBMITTED

The Glass at the Left Is Specially Designed for Counting the Warp and the Filling Threads in All Kinds of Fabric. That at the Right Is a Combination Paperweight and Magnifying Glass and Serves To Keep the Fabric Flat While It Is Being Inspected, without Requiring the Use of Additional Weights or the Hands

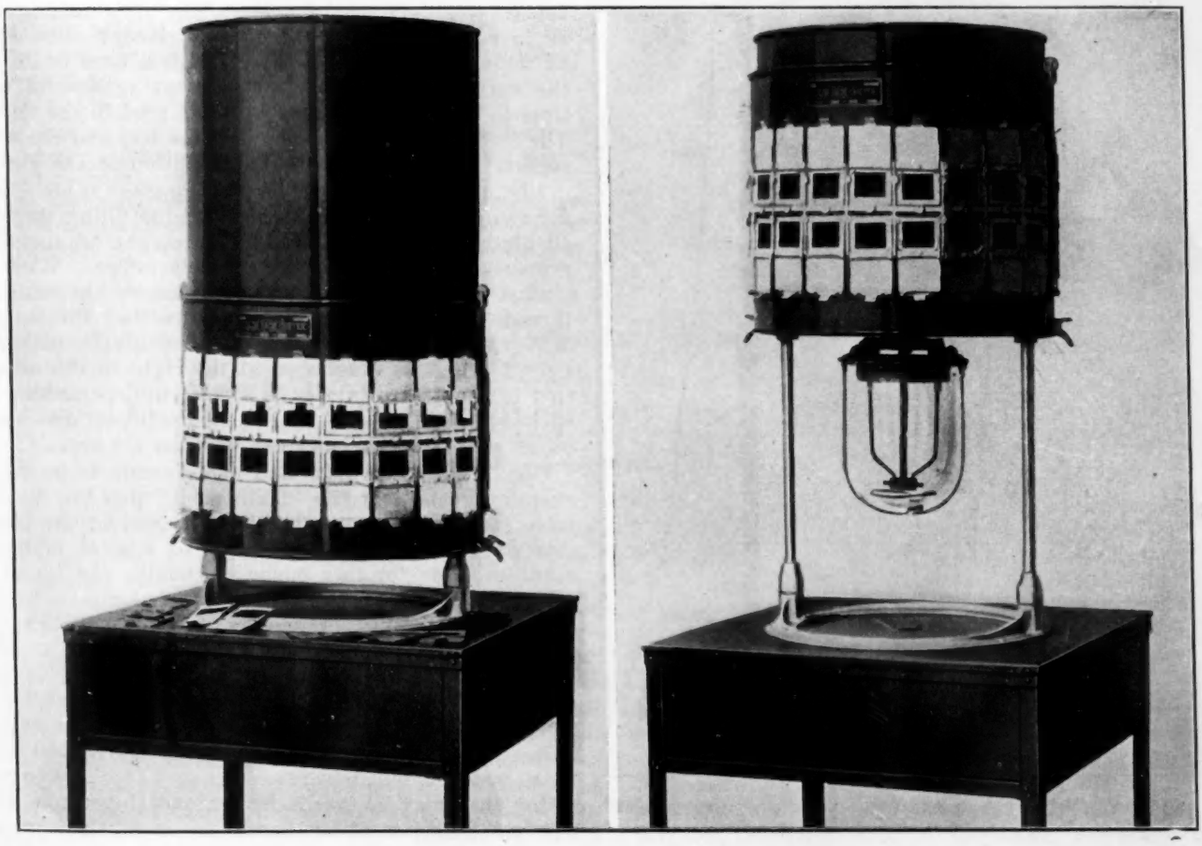

FIG. 3—TWO VIEWS OF A DEVICE FOR TESTING THE FASTNESS OF COLOR

The View at the Left Shows the Testing Position, While in That at the Right the Cabinet Section Has Been Raised. With This Device the Quality of the Dyes Used in Carpet, Cloth and Silk Can Be Ascertained Quickly Instead of Taking Several Weeks To Test These Materials on the Roof in the Daylight

the coarse wools for making the carpet from the mountainous regions of Russia and Austria, the jute for the back of the carpet from India, the cotton from the southern part of our Country, the silk for the curtains from Japan and China, the mahogany in the vanity cases from San Domingo, the artificial silk in the passementerie and trimmings from Belgium, and the dyes used in the cloths from Germany? Many countries give their share toward producing the beautiful interior of the closed car of today.

Testing Material

Perhaps it would be well to show the different methods employed in testing closed-car fabrics, in determining their tensile-strength, the quality of the raw material used and the weight per running yard, 54 in. wide.

Fig. 1 shows an improved hand-operated cloth-testing machine that determines the warp strength and the filling strength of a piece of fabric. If it is desired to know the breaking-test of the warp threads of a piece of cloth, the cloth can be clamped securely in this machine and, when the handle is turned and pressure is put on the warp threads, the dial will register the exact number of pounds at which the break in the cloth occurs. By inserting a piece of cloth in the machine with the weft or filling threads running up and down, a test can also be made of the filling threads. Every body engineer who has to examine closed-car fabrics should have one of these machines and should test out the tensile-strength of the original sample and, occasionally during the course of the season's production, see that the manufacture is conforming to the standard of the original sample submitted.

Fig. 5—Daylight Lamp for Examining the Color and the Finish of Cloth

Due to the Differences in the Light in an Office from One Hour to the Next, an Artificial Unchanging Standard Is Necessary when Examining Colors and Matching Shades. The Light Given by This Lamp Is a True North Light Found on the Roof at the Middle of a Mid-Summer's Day

Fig. 2 shows a cloth-sampling scale. No company buying cloth should be without one of these scales for weighing the original sample submitted by the manufacturer and then making a test occasionally to see that the cloth delivered to it is up to the standard of the sample submitted. With this scale are a circular steel die and a wood-cutting block which ensure that every sample will be exactly the same size.

The weight per running yard of any cloth may be determined simply by weighing a small sample. The cloth is placed on the wooden block and, with the steel die, a sample having an area of 4 sq. in. is stamped out. This sample is then placed in the fork at the end of the scale-beam and the beam is brought to a balance. The indication on the beam in ounces multiplied by the width of the cloth in inches gives directly the weight per running yard.

When a manufacturer quotes on a piece of fabric as being 14, 18 or 22 oz., have that sample weighed immediately, to see if that particular sample comes up to the factory requirements, by placing the circular disk of cloth in the little fork of the scale and moving the two weights to get the exact weight of the small sample; then, by multiplying the weight obtained by 54 in., you will have the exact weight of a 54-in. cloth in ounces per running yard.

Fig. 3 shows one of the latest methods of testing fabrics for fastness of color. The fade-ometer should be in every well-equipped body engineer's office so that he can ascertain the quality of the dyes used in the cloth, the carpet and the silk without taking several weeks' time to test these materials on the roof in the daylight. The testing position is shown at the left and the cabinet section is shown in the raised position at the right.

Fig. 4 at the left shows a counting-glass made specially for counting the warp threads and the filling threads in all kinds of fabric. This is a necessary adjunct to the properly equipped body-engineer's office. With this glass, it will be absolutely practicable to count the threads of carpets and cloths to see that the materials delivered conform to the samples originally submitted. Use of the glass illustrated at the right in the examination of motor-car fabrics is almost indispensable. It is without question one of the most useful articles a cloth-buyer or a body engineer can have on his desk.

One of the most important experiments to be made in examining cloth is the "boiling-out" process, to determine just how much cotton is contained in the piece of material you are purchasing. No special boiling-out outfit is made for this purpose, but one can be secured very readily by purchasing a Sterno lamp, a fireproof china bowl holding perhaps ½ pt., and a 1-lb. bottle of caustic-soda pencils. Light the Sterno lamp under the bowl, which should be about two-thirds filled with water, and into this bowl place from 4 to 6 in. of caustic-soda pencils. Then put the piece of fabric into the water; if it is all wool, it will soon dissolve entirely. The caustic soda, however, will have no effect on any carded or spun cotton that may be in the fabric, and the cotton will be left in the bottom of the bowl.

Should you care to get the exact proportions of cotton and wool, weigh the piece of material accurately before it is put into the caustic-soda solution; then, by weighing

the cotton residue after it has been thoroughly washed and dried, you can tell exactly the proportions of wool and cotton in the fabric.

Fig. 5 shows one of the improved daylight lamps that are invaluable for the examination of cloth as regards its color and finish. The light in your office at nine o'clock in the morning is entirely different from the light that comes through your window at noon, and the light coming in at four o'clock in the afternoon is entirely different from the light in the morning or at noon, so that it is almost imperative, for the proper examination of colors and the matching of shades, to have an artificial standard that is always the same. The light given by Macbeth lamps is the true north-light found on the roof at midday in mid-summer and is the standard that you should always work by.

MARCH COUNCIL MEETING

THE meeting of the Council held in New York City on March 13 was attended by President Crane, Vice-Presidents Strickland and Pope, Councilors Rumney, Scaife, Hunt and Brumbaugh, and Treasurer Whittelsey. The financial statement as of Feb. 29, 1924, showed a net balance of assets over liabilities of $150,440.08, this being $29,092.75 more than the corresponding figure on the same day of 1923. The net revenue of the Society for the first 5 months of the current fiscal year amounted to $98,193.78. The operating expense during the same period was $88,264.95.

Sixty-seven applications for individual membership were approved. The following transfers in grade of membership were made: From Junior to Member, Lawrence D. Bell, W. W. Slaght and R. Leon Smith; Junior to Associate, William P. Crowell, George J. Dietz, Jr., and A. P. Perlov; Associate to Member, Arthur W. Einstein.

It was reported that during the first 2 months of 1924, 134 applications for membership, including student enrollment, had been received, as compared with 177 applications received during the same months of 1923.

The following appointments to Divisions of the Standards Committee were approved:

Agricultural Power Equipment Division—John Mainland

Iron and Steel Division—W. R. Shimer and C. W. Simpson

Isolated Electric Lighting Division—C. R. Alling

J. H. Nelson and C. L. Burns were appointed to serve on the Advisory Committee on Structures and Fabricated Metals of the Bureau of Standards.

K. L. Herrmann was appointed to serve as representative on the Subcommittee that will standardize Tee Slots, under the Procedure of the American Engineering Standards Committee.

A petition for the establishment in Milwaukee of a Probationary Section of the Society was granted.

A report of the Special Committee on Society and Sections Organization was accepted, this relating to various matters with regard to the conduct of the Sections that have been discussed recently. The report is given in full in the Chronicle and Comment Department of this issue of THE JOURNAL.

In view of the practice authorized by the Council of charging guests for admittance to some of the National Meetings of the Society, Rule 10 that related in part to the bringing of guests by members to such meetings was abolished.

Discussion was had of the meetings scheduled for 1924.

The following personnel of the Committees named was approved:

HIGHWAYS COMMITTEE

B. B. Bachman, *Chairman*

R. S. Begg — W. E. Lay
H. C. Dickinson — C. M. Manly
S. H. Woods

ORDNANCE ADVISORY COMMITTEE

W. G. Wall, *Chairman*

H. W. Alden — P. E. Holt
B. B. Bachman — C. M. Manly
G. W. Dunham — A. F. Masury
Dent Parrett

RESEARCH COMMITTEE

H. L. Horning, *Chairman*

H. W. Alden — T. J. Litle, Jr.
B. B. Bachman — Thomas Midgley, Jr.
O. C. Berry — F. C. Mock
H. M. Crane — A. L. Nelson
H. C. Dickinson — S. W. Sparrow
W. S. James — P. S. Tice
E. A. Johnston — J. G. Vincent
C. F. Kettering — E. P. Warner
R. E. Wilson

The next meeting of the Council will be held in the Middle West early in May.

CHRONICLE AND COMMENT

(*Concluded from p.* 365)

propriating monies for the use of the Sections. This formula provides for a basic appropriation of $250 to each Section, regardless of its size. It is stipulated, however, that the appropriation to each Section each year shall not be less than $500. Each Section receives $1 for each Society member in good standing, as of Oct. 1, who resides within the territory of the Section as defined by the Council; $2 for each member of the Section who has paid Section dues and is in good standing therein in April of each year; and $3 for each member enrolled who resides outside of the respective territory and not in any other Section's territory. A number of inevitable variables, of course, affect the amount of money a Section will need during a given season. Of two Sections of the same size and potentiality, one may be unusually active and the other unduly inactive. The number of meetings held per year is a factor and also, of course, the actual merit and value of the meetings that are held.

The members of the Sections Committee now serving under the chairmanship of Mr. Hunt are: John Younger, chairman of the Cleveland Section; J. A. Anglada, past-chairman of the Metropolitan Section; F. F. Chandler, chairman of the Indiana Section; A. W. S. Herrington, nominated as chairman of the Washington Section; George L. McCain, nominated as chairman of the Detroit Section; H. O. K. Meister, secretary of the Mid-West Section; R. E. Northway, chairman of the New England Section; Phil N. Overman, secretary of the Minneapolis Section; H. W. Slauson, past-chairman of the Metropolitan Section; and J. W. White, nominated as chairman of the Buffalo Section.

Vibration in Four-Cylinder Engines

By L. C. Freeman[1]

Detroit Section Paper

THE author states that so far as the passengers are concerned the effects of four-cylinder-engine vibration can be eliminated as completely as though the cause were removed. An analysis of this vibration-reduction method is presented. Although it is neither complete nor mathematically exact, the author believes it sufficiently so to permit practical applications to be made. The construction is such that energy is absorbed at a rate that makes resonance impossible.

A detailed description of how the center of oscillation of the engine is determined precedes a discussion of the resultant inertia-force characteristics. The front support is in the form of a thin-leaf semi-elliptic spring having sufficient interleaf friction to counteract the energy input per oscillation at the synchronous frequency.

Mr. Freeman believes that, even if future piston developments necessitate a slight increase in weight, vibration can still be controlled by providing the necessary amount of friction in the front supports.

VIBRATION in four-cylinder engines is due principally to the unbalanced inertia forces of the reciprocating parts; it is solely these forces that are considered here. At any speed, two factors govern; the connecting-rod to crank ratio and the weights of the reciprocating parts. It would seem that, in recent aluminum-alloy piston and connecting-rod developments full advantage has been taken of the present possibilities of weight reduction and, incidentally, it seems probable that lessened vibration, rather than increased thermal conductivity or lowered bearing pressures, has been the controlling factor in the increasing use of aluminum pistons in four-cylinder engines.

Increase in connecting-rod to crank ratio means an increase in weight and cost; so, present-day practice probably results in economic, if not in mechanical, balance. We always try to eliminate the cause of objectionable effects but, when this is not feasible, they sometimes can be neutralized or offset by other means. So far as the passengers are concerned, the effects of four-cylinder-engine vibration can be eliminated as completely as though the cause were removed. In one case, this has been accomplished by a construction such that energy is absorbed at a rate that makes resonance impossible. This analysis is neither complete nor mathematically exact, but it is believed that sufficient indication has been given of the method so that practical application can be made.

Vibration-Reduction Method

The method is to locate the rear supports so that the center of percussion of the unit falls in the plane of the resultant of the unbalanced inertia-forces, and then to provide a vibration or energy-absorbing element at another point so as to prevent resonance in the frame structure as its natural frequencies are approached or passed through. The resultant of the unbalanced inertia-forces of the reciprocating parts acts in a plane midway between cylinders Nos. 2 and 3. The moment of this resultant force about a transverse axis through the center of oscillation tends to rotate the engine about this axis; it results in an approximately vertical movement at the front supports and no tendency whatever for the center of oscillation to move relative to the car frame. This, then, is the place at which the rear engine-supports should be located and, inasmuch as the centers of suspension and oscillation are interchangeable, the center of percussion is thereby brought into the plane of the resultant of the unbalanced inertia-forces. I believe this to be strictly true when the engine is supported only at the original axis of oscillation; and that it is entirely independent of the frequency or the magnitude of the forces acting, so long as the movement is small. If the unit is rotated about the axis into an approximately horizontal position and maintained there by a flexible support located in the plane of the resultant inertia-force, there is still no reaction at the rear supports. In other words, we have so far found one point on the engine where it can be attached to the frame without the transmission of any vibration at that point.

To find the center of oscillation:

(1) Determine the center of gravity of the engine, or powerplant unit

(2) Suspend the engine from the axis formed by the intersection of a plane intersecting at right angles the plane of the cylinder axes midway between the axes of cylinders Nos. 2 and 3 with a plane containing the center of gravity, these planes being at right angles to the plane containing the cylinder axes and to each other

(3) Observe the time t, in seconds, of a single oscillation of the engine so suspended, and compute the length L of the equivalent simple pendulum by the formula $L = 12\ gt^2/\pi^2$, in which g, the acceleration of gravity, is 32.2 ft. per sec. per sec.

(4) Locate the center of percussion by measuring the distance L in inches in the direction of the center of gravity from the point determined by the intersection of the three planes. A line in the plane of the center of gravity as defined in (2), parallel to the axis of suspension and passing through the center of percussion, will be the desired axis of the engine support which should, theoretically, be in the form of a trunnion. With the engine suspended from this new axis, the original axis of suspension then becomes the center of percussion and is in the plane of the unbalanced inertia-forces of the reciprocating parts

Resultant Inertia-Force Characteristics

The inertia forces of the reciprocating parts can be represented by the summation of an infinite series of cosine curves, progressively increasing in frequency and decreasing in amplitude. Of these the first overtone is the most important and has a frequency of 2 per revolution. These forces are acting all the time the engine is running, but it is a matter of common knowledge that they are in evidence at certain particular speeds, usually not the highest speeds at which the forces are the greatest, as they vary as the square of the speed. The reason is that the amplitude of the resultant vibrations

[1] M.S.A.E.—Executive engineer, Maxwell Motor Corporation, Detroit.

of the frame is very small, except where its natural frequencies are approached or passed through. It might be possible to make a frame so stiff that it would respond only to the second overtone; it would seem, from this standpoint, that the higher the engine speed is the stiffer the frame should be. However that may be, if an energy-absorbing element is introduced between the engine and the frame, the amplitude of the frame vibration can be kept so low as to be unnoticed even at the resonant frequencies. Possibly this can best be illustrated by a child's swing being kept in motion by the application of intermittent impulses in tune with the natural frequency of the swing. If the frictional loss at the pivots plus the wind resistance plus the friction caused by the dragging of a child's feet on the ground per oscillation is not equal to or greater than the energy input per oscillation, the amplitude will increase; if it is greater, the amplitude will decrease. This is exactly what has been accomplished by making the front support in the form of a thin-leaf semi-elliptic spring having sufficient interleaf friction to counteract the energy input per oscillation at the synchronous frequency. Of course, the resilient support could be made so that it would have little or no internal friction and the necessary friction could be introduced by another element such as a shock-absorber.

The displacement of the front support from its theoretically correct position does introduce some errors, as there will be a resultant reaction at the rear support. This should be dependent, however, on the stiffness of the spring and, practically, it has been found negligible. It is believed, though, that the location of the rear support is very important, although the method of attachment to the frame can be modified.

As the work to be done varies only directly as the weight of the piston, I believe that vibration, even if piston developments necessitate a slight increase in weight, can still be controlled by providing the necessary amount of friction in the front supports. Undoubtedly the same results can be accomplished approximately by other means, but this construction costs less than the one it replaced.

CHASSIS LUBRICATION

(*Concluded from p.* 430)

the same as when they are used with a bronze bushing. The bushings were all plain and had no oil-grooves, except that the bronze bushing at the front right rear-spring had a double spiral oil-groove, the profile of the groove being reproduced on the bearing surface of the spring-bolt.

After traveling 20,000 miles in 1 year of operation that included winter months during which sustained temperatures that were below 0 deg. fahr. were of common occurrence, a test chassis operated by a manufacturer disclosed an average wear of 0.0015 in. for spring-bolts with a diameter of ¾ in., and steering-knuckle pivots with a diameter of 1 in. The bolts were made from No. 1020 S.A.E. steel, 65 to 70 hard by the Shore test.

Summarizing the claims made for this chassis-lubricating system, the conclusions reached are as follows:

(1) A simple, dependable chassis-lubrication system that will lubricate all chassis bearings efficiently can be incorporated in the chassis with few complications and very little added expense

(2) Longer life, the elimination of annoying squeaks and rattles, and improved riding and handling qualities will result from the adoption of this system

(3) The reservoir and the pump constitute a sturdy unit that will function during the life of the chassis with no attention other than that required for filling the reservoir and occasionally cleansing the screen in the drain-plug

(4) The system of oil-delivery control is such that ⅛ cu. in. of oil will lubricate the bearings of the average chassis efficiently, so that every bearing surface will show a film of oil. Lubricant is not forced out around the outlets to soil the chassis and collect dirt. Any predetermined volume of oil, from 1 drop to any desired volume, is delivered positively at each outlet every time the pump plunger is depressed

(5) The system of oil delivery provides for a shot of oil at each bearing immediately after the pump plunger is operated and for a continuous, slowly decreasing feed for several hours

(6) The oil pressures developed at the outlets with one stroke of the pump plunger vary from 1 to 10 lb. per sq. in., depending on the volume of oil delivered and the fit of the bearing supplied

(7) Failure in one or in any number of delivery lines will not affect the operation of the remaining delivery-lines

(8) The system will lubricate efficiently a chassis operated at sustained low temperatures

(9) The constructions employed to lubricate various chassis units provide means to lubricate these units with adequately protected tubes and connections that move as a rigid part with the unit, thus eliminating swivel connections and projecting parts that are subject to damage. Once properly installed, they will function during the life of the chassis

(10) In general, all service-work on the chassis can be accomplished without disturbing the connections or the tubes of the lubrication system

REPARATIONS

ASIDE from the Interallied loans, France demands that Germany pay her 26 milliards of gold marks, which she claims represents a fair value for the restoration of the devastated districts. In addition to this, Belgium demands 5 milliards of gold marks and Great Britain 14 milliards, which with the amounts that would have to be paid the other Allies would bring the total reparations that Germany would have to pay to from 48 to 50 milliards of gold marks, or roundly $12,500,000,000. This sum is in addition to the demand of France that as she makes payments on her Interallied indebtedness Germany must also make equivalent payments to her. But, on the other hand, there is included within this total in the 14 milliards that Great Britain demands of Germany a return of the funds which Great Britain must in her turn pay the United States to cancel her indebtedness to this Country.—F. I. Kent.

Personnel of 1924 Technical Committees

THE accompanying personnel of technical Committees of the Society and of representatives on the Committees of Governmental Bureaus and Departments and other organizations practically completes the personnel appointed for 1924. In the case of the Standards Committee, the names of appointees on the several Divisions who had accepted up to the time the February issue of THE JOURNAL went to press, were printed in that issue. The personnel of Special and Cooperating Committees of the Society and the representatives on other committees is published in this issue to give the members a more definite idea of the fields of work in which the Society is taking an active part and the men who are participating directly. It has been found that many members of the Society do not have a very broad conception of the work that is being done and as a result they do not get as much benefit from their membership in the Society as they might, and the Committees in many cases find it more difficult to obtain the cooperation of the membership in general in much of their work. The personnel of certain committees, especially the Standards Committee and some of the Sectional Committees, changes more or less during the year but in general will remain as published herein.

The Standards Committee is divided into 28 main Divisions classified according to types of vehicle, major automotive component units, parts and materials. Divisions are appointed annually and handle groups of subjects. They are further subdivided into Subdivisions, each of which handles a specific subject.

Special and Cooperating Committees are appointed either temporarily or permanently to handle specific subjects or such subjects as may not come within the classification of the Divisions. Their reports as a rule are eventually passed upon by the Standards Committee.

Sectional Committees are classified into two groups, one for which the Society is a sponsor and the other on which the Society only appoints representatives. Under the rules of procedure of the American Engineering Standards Committee, of which the Society is a member body, reports issued by Sectional Committees for which the Society is sponsor, must be approved by the Society by regular Standards Committee procedure before they are finally approved by the American Engineering Standards Committee. Reports from Sectional Committees on which the Society is only represented need not necessarily be approved by the Society.

The work of Committees and Governmental Departments and Bureaus and of other organizations does not as a rule proceed through the Standards Committee but may be acted upon by the Council of the Society in special cases.

STANDARDS COMMITTEE

E. A. Johnston, *Chairman*	International Harvester Co.
C. M. Manly, *First Vice-Chairman*	Manly & Veal
C. C. Carlton, *Second Vice-Chairman*	Motor Wheel Corporation

AERONAUTIC DIVISION

H. M. Crane, *Chairman*	New York City
H. L. Pope, *Vice-Chairman*	Wright Aeronautical Corporation
Porter H. Adams	Representing National Aeronautic Association of United States Army
W. L. Gilmore	Curtiss Aeroplane & Motor Co., Inc.
L. M. Grant	Naval Aircraft Factory
L. M. Griffith	National Advisory Committee for Aeronautics
Otto H. Hamm	Air Service
J. L. Harkness	L. W. F. Engineering Co.
Grover C. Loening	Loening Aeronautical Engineering Corporation
E. C. Richard	Air Mail Service
William B. Stout	Stout Metal Airplane Co.
B. Douglas Thomas	Thomas-Morse Aircraft Corporation
R. H. Upson	Aircraft Development Corporation
Edward Wallace	Glenn L. Martin Co.
L. M. Woolson	Packard Motor Car Co.
Paul G. Zimmerman	Aeromarine Plane & Motor Co., Inc.

AGRICULTURAL POWER EQUIPMENT DIVISION

J. F. Max Patitz, *Chairman*	Allis-Chalmers Mfg. Co.
O. W. Sjogren, *Vice-Chairman*	University of Nebraska
J. B. Bartholomew	Avery Co.
C. E. Frudden	Hart-Parr Co.
A. H. Gilbert	Rock Island Plow Co.
R. O. Hendrickson	J. I. Case Plow Works Co.
Pliny E. Holt	Holt Mfg. Co.
John Mainland	Advance-Rumely Co.
A. W. Scarratt	Minneapolis Steel & Machinery Co.
G. A. Young	Purdue University
O. B. Zimmerman	International Harvester Co.

AXLE AND WHEELS DIVISION

C. C. Carlton, *Chairman*	Motor Wheel Corporation
C. S. Dahlquist, *Vice-Chairman*	Timken-Detroit Axle Co.
R. S. Begg	Jordan Motor Car Co.
T. V. Buckwalter	Timken Roller Bearing Co.
R. J. Burrows	Clark Equipment Co.
G. W. Carlson	Eaton Axle & Spring Co.
R. E. Clingan	Bock Bearing Co.
H. E. Derr	International Harvester Co.
F. W. Gurney	Gurney Ball Bearing Co.
F. P. Hall, Jr.	Salisbury Axle Co.
G. W. Harper	Columbia Axle Co.
E. R. Jacobi	Hayes Wheel Co.
G. L. Lavery	West Steel Casting Co.
H. J. Ludwick	Budd Wheel Co.
D. D. Ormsby	Brown-Lipe-Chapin Co.
H. Spur	Russell Motor Axle Co.
S. O. White	Warner Gear Co.

BALL AND ROLLER BEARINGS DIVISION

F. W. Gurney, *Chairman*	Gurney Ball Bearings Co.
T. V. Buckwalter, *Vice-Chairman*	Timken Roller Bearing Co.
J. T. R. Bell	Rollway Bearing Co., Inc.
G. R. Bott	Norma Co. of America
H. E. Brunner	S. K. F. Industries, Inc.
E. R. Carter, Jr.	Fafnir Bearing Co.
D. F. Chambers	Bearings Co. of America
R. E. Clingan	Bock Bearing Co.
L. A. Cummings	Standard Steel & Bearings, Inc.
F. G. Hughes	New Departure Mfg. Co.
G. L. Miller	Gilliam Mfg. Co.
R. G. Schaffner	Bower Roller Bearing Co.
W. R. Strickland	Cadillac Motor Car Co.
R. E. Wells	Hyatt Roller Bearing Co.
H. Wickland	U. S. Ball Bearing Mfg. Co.

CHAIN DIVISION

H. S. Pierce, *Chairman*	Link Belt Co.
W. J. Belcher, *Vice-Chairman*	Whitney Mfg. Co.
G. M. Bartlett	Diamond Chain & Mfg. Co.
W. F. Cole	Baldwin Chain & Mfg. Co.
H. F. L. Funke	Herbert F. L. Funke Co., Inc.
K. L. Herrmann	Studebaker Corporation of America
M. C. Horine	International Motor Co.
J. C. Howe	American High Speed Chain Co.
F. L. Morse	Morse Chain Co.
L. B. Sperry	International Harvester Co.

ELECTRIC VEHICLE DIVISION

J. G. Carroll, *Chairman*	Walker Vehicle Co.
H. M. Pierce, *Vice-Chairman*	Ward Motor Vehicle Co.
G. L. Bixby	Detroit Electric Car Co.
A. K. Brumbaugh	Autocar Co.
E. L. Clark	Commercial Truck Co.
C. H. Meeker	Lansden Co., Inc.
Charles A. Skinner, Jr.	New York Edison Co.

ELECTRICAL EQUIPMENT DIVISION

F. W. Andrews, *Chairman*	Eisemann Magneto Corporation
T. L. Lee, *Vice-Chairman*	North East Electric Co.
C. R. Alling	Underwriters' Laboratories
Azel Ames	Kerite Insulated Wire & Cable Co.
F. A. Bonham	Durant Motors, Inc.
D. W. Burke	Auto Electric & Service Corporation
S. W. Colvard	Dayton Engrg. Lab. Co.
A. M. Dudley	Westinghouse Electric & Mfg. Co.
P. J. Durham	P. J. Durham Co., Inc.
S. F. Evelyn	Continental Motors Corporation
C. F. Gilchrist	Electric Auto-Lite Co.
W. S. Haggott	Packard Electric Co.
F. C. Kroeger	Remy Electric Co.
B. M. Leece	Leece-Neville Co.
A. D. T. Libby	Automotive Electric Association
Charles Marcus	Eclipse Machine Co.
E. A. Robertson	Splitdorf Electrical Co.
B. M. Smarr	General Motors Corporation
C. H. Williams	Studebaker Corporation of America
Ernest Wooler	Cleveland Automobile Co.

ENGINE DIVISION

R. J. Broege, *Chairman*	Buda Co.
W. C. Ware, *Vice-Chairman*	Fay & Bowen Engine Co.
A. A. Bull	Northway Motor & Mfg. Co.
P. J. Dasey	Wellman-Seaver-Morgan Co.
W. V. DeGalan	Paige-Detroit Motor Car Co.
R. F. Droege	Templar Motors Corporation
S. F. Evelyn	Continental Motors Corporation
J. B. Fisher	Waukesha Motor Co.
G. Walker Gilmer, Jr.	L. H. Gilmer Co.
Pliny E. Holt	Holt Mfg. Co.
A. F. Milbrath	Wisconsin Motor Mfg. Co.
Louis Schwitzer	Automotive Parts Co.
M. J. Steele	Packard Motor Car Co.
Joseph Van Blerck	Joseph Van Blerck Engine Corporation

FRAMES DIVISION

C. C. Bowman, *Chairman*	Standard Motor Truck Co.
O. B. Harmon, *Vice-Chairman*	Parish & Bingham Co.
E. A. DeWaters	Buick Motor Co.
W. A. McKinley	Midland Steel Products Co.
E. S. Vande Mark	Parish Mfg. Corporation
Ernest Wooler	Cleveland Automobile Co.

IRON AND STEEL DIVISION

F. P. Gilligan, *Chairman*	Henry Souther Engineering Corporation
J. M. Watson, *Vice-Chairman*	Hupp Motor Car Corporation
J. R. Adams	Midvale Co.
R. J. Allen	Rolls-Royce of America, Inc.
H. T. Chandler	Vanadium Corporation of America
Norman Conn	Minneapolis Steel & Machinery Co.
B. F. Courtright	Wisconsin Steel Works, International Harvester Co.
J. D. Cutter	Climax Molybdenum Co.
L. A. Danse	Cadillac Motor Car Co.
C. N. Dawe	Studebaker Corporation of America
B. H. DeLong	Carpenter Steel Co.
E. W. Ehn	Timken Roller Bearing Co.
A. P. Eves	International Harvester Co.
H. L. Greene	Willys-Overland Co.
G. F. Harper	Allis-Chalmers Mfg. Co.
E. J. Janitzky	Illinois Steel Co.
J. B. Johnson	Air Service
F. C. Langenberg	Ordnance Department
F. E. McCleary	Dodge Bros.
J. A. Mathews	Crucible Steel Co. of America
C. S. Moody	C. L. Best Tractor Co.
J. H. Nelson	Wyman-Gordon Co.
G. L. Norris	Vanadium Corporation of America
W. C. Peterson	Standard Automotive Parts Co.; Fredericksen Co.
W. H. Phillips	R. D. Nuttall Co.
S. P. Rockwell	Representing American Gear Manufacturers Association
M. P. Rumney	Detroit Steel Products Co.
C. F. W. Rys	Carnegie Steel Co.
R. B. Schenck	Buick Motor Co.
M. H. Schmid	United Alloy Steel Corporation
W. R. Shimer	Bethlehem Steel Co.
C. W. Simpson	White Motor Co.
T. H. Wickenden	International Nickel Co.
H. M. Williams	General Motors Research Corporation

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F. C. Barton, *Vice-Chairman*	General Electric Co.
C. R. Alling	Underwriters' Laboratories
L. F. Burger	International Harvester Co.
C. B. Dicksee	Westinghouse Electric & Mfg. Co.
G. M. Gardner	Globe Electric Co.
C. F. Gilchrist	Electric Auto-Lite Co.
L. W. Holt	Holt Power Light Co.
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L. C. Porter	Edison Lamp Works of the General Electric Co.
E. S. Preston	Chicago Electric Mfg. Co.
C. D. Ryder	Cincinnati Victor Co.
C. E. Salisbury	Hupp Motor Car Corporation
A. J. Scaife	White Motor Co.
Ewald K. Schadt	Cadillac Motor Car Co.
B. M. Smarr	General Motors Corporation
J. C. Stearns	Culver-Stearns Mfg. Co.
F. W. Todd	Accessories Mfg. Co.
T. I. Walker	Providence Base Works of the General Electric Co.
C. H. Williams	Studebaker Corporation of America
E. E. Wood, Jr.	Miniature Incandescent Lamp Corporation
Ernest Wooler	Cleveland Automobile Co.
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W. E. Jominy, *Vice-Chairman*	University of Michigan
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K. G. Mackenzie	Texas Co. (Also representing the American Society for Testing Materials)
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W. E. Perdew	Sinclair Refining Co.
W. D. Reese, Jr.	Yellow Sleeve-Valve Engine Co.
H. J. Saladin	Standard Oil Co. of Indiana
H. G. Smith	Gulf Refining Co.
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Clyde Jennings	*Motor Age*
Herbert Chase	*Automotive Industries*
Leonard Ochtman, Jr.	Joseph Van Blerck Engine Corporation
B. M. Smarr	General Motors Corporation
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Cornelius T. Myers	Rahway, N. J.
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Kingston Forbes, *Vice-Chairman*	Buick Motor Co.
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A. R. Lewellen	Chevrolet Motor Co.
J. L. Rupp	Westinghouse Union Battery Co.
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H. M. Crane	New York City
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G. J. Mead	Wright Aeronautical Corporation
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PATRICK L. HUSSEY

AFTER having had a lengthy career in charge of the racing affairs of several widely known companies in the bicycle business, Patrick L. Hussey entered the automobile field in the days when its development was only beginning. Veterans of the automotive industry will therefore be sad to learn of his death on Feb. 23, in Cleveland, his birthplace.

Educated in the schools of Cleveland and equipped with practical experience gained early, he was superintendent of the Davis Sewing Machine Co. from 1894 to 1901. After a brief term as manager for the original Cadillac Motor Car Co., he established the Hussey Drop Forging & Mfg. Co. and operated this organization until 1907, it being engaged in making bicycle and automobile parts. In 1908 he was associated with the Halcomb Steel Co., Syracuse, N. Y., as a special representative for automobile steels.

Later, it was his misfortune to become blind, but for several years subsequent to his enforced retirement from active business he was a familiar figure at the automobile shows where he greeted his old friends, recognizing many of them by their tones of voice.

Mr. Hussey was elected to Member grade in the Society in June, 1908.

GEORGE S. CAWTHORNE

MEMBERS of the Society will regret to learn of the death of George S. Cawthorne, chief engineer in charge of production, plant and maintenance, for Master Trucks, Inc., Chicago, on Feb. 19, aged 49 years. His decease followed a malignant throat infection of 2 months' duration. He was born, Nov. 2, 1874, at Chicago, and received his engineering education at the Columbian College in that city, attending evening classes there from 1889 to 1892.

Following his experience as machinist and draftsman with several different companies from 1889 to 1912, he became connected with the service department of the Thomas B. Jeffrey Co. and in 1914 changed this connection to be superintendent for the Best Service Truck Co., St. Louis. From 1916 to 1918 he was with the Commercial Car Service Co., Chicago, as engineer and, after 1 year with the United Four Wheel Drive Co., Chicago, as superintendent and engineer, he formed the connection with Master Trucks, Inc., that continued until his death.

Mr. Cawthorne was elected to Member grade in the Society, Dec. 10, 1919.

THE DOLLAR ABROAD

THE popularity of the dollar abroad has been widely heralded in the press. The circulation of one, two and five dollar bills in Germany has been described as a "flood;" the dollar has become the medium of exchange in many countries whose currencies are so debased that their nationals are clamoring for American money in preference to their own. One New York bank last summer shipped $5,000,000 to a Latvian address, presumably for use in Russia.

Estimates of the volume of American currency holdings abroad have ranged from $750,000,000 down to a much more modest figure. There is no way of determining what the circulation of money is even in the United States. Currency is not called in for redemption at any one time. The Treasury itself does not know how much has been lost, how much has gone up in fire or disappeared in rats' nests. Only once since the Government began the issuance of coins and notes has a charge-off been made to account for this factor, but this profited the Treasury about $50,000,000. While the imports and exports of gold are recorded by the Government departments, included in the term "gold" are currency, specie and gold. Since the Treasury lifted the ban on the foreign shipments of money, no means of recording its exodus to foreign lands is available.

During a period when shipments of American currency abroad have been proceeding in unprecedented volume, Europe has kept just a little over $2,000,000 per month more than she has sent back to the United States. During the war, when there were millions of khaki-clad Americans in France in the expeditionary forces, great sums of money were spent there. Later, when the army of occupation camped on the Rhine, the soldiers distributed the dollars widely in Germany. While it is reasonable to believe that the thrifty Germans, with an eye to the future, salted away some of the precious greenbacks, the demand for things that the dollar would buy called most of the American currency home.—*Journal of the American Bankers' Association.*

Practical Methods of Engine-Balancing

By L. L. ROBERTS[1]

DETROIT SECTION PAPER *Illustrated with* PHOTOGRAPHS

REMARKING upon the progress made by the builders of machine-tools in providing equipment for locating and correcting the unbalance of rotating parts, the author divides into three major groups the units of a motor car that require particular attention and treatment to assure a smooth-running mechanism and gives details of the actual methods employed by the company he represents to balance the parts that constitute each group in the vehicles it produces.

Representatives of the engineering and the manufacturing departments of this company studied the subject intensively and determined the types of balancing-machine and the methods to be employed, and special balancing equipment was devised also. Details of the balancing practice for crankshafts, flywheels, connecting-rods, clutches and propeller-shafts are presented and the subjects of impulse balance and the maintenance of balance for assemblies of parts are discussed.

THE units of a motor car that require particular attention and treatment to assure a smooth-running mechanism can be divided into the three major groups of (*a*) the engine with its crankshaft, flywheel, connecting-rods, pistons and combustion-chambers; (*b*) the clutch and the transmission; and (*c*) the propeller-shaft, including the universal-joints. Other important units and parts set up vibrations and cause noise if the eternal vigilance required in the construction of high-grade motor-cars is relaxed the least bit in regard to fit and alignment, but the scope of this paper is confined to the three groups mentioned.

Considerable progress has been made by machine-tool builders in providing equipment for locating and correcting the unbalance of rotating parts, and the problem of selecting the machine best suited for the particular part to be balanced requires much study and investigation on the part of the engineers who specify the purchase of manufacturing equipment. Our company designated representatives of the engineering and the manufacturing departments to make a study of balancing-machines on the market, with a view to selecting machines best suited for balancing the car parts it manufactures.

CRANKSHAFTS

Fig. 1 is a photograph of our eight-cylinder-engine crankshaft, which is very similar to that of our six-cylinder engines except for the different number of crank-throws. The crankshafts of both types of engine are machined all over. Of course, if it were possible to hold absolutely to certain dimensions, it would be unnecessary to make any balancing corrections.

After checking-up about 100 crankshafts carefully we found that, from a manufacturing viewpoint, certain so-called unimportant dimensions such as the thickness and the contour of the crank-arms would cause the crankshaft to be considerably out-of-balance if machined to the extreme limits allowed either way of ± 0.010 in. Our first step was to determine a suitable method for correcting the existing unbalance and, with this in mind,

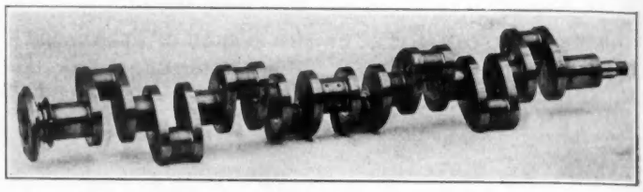

FIG. 1—CRANKSHAFT OF THE PACKARD EIGHT-CYLINDER ENGINE

These Crankshafts, Like Those of the Packard Six-Cylinder Engine Are Machined All Over. If the Thickness and the Contour of the Crank Arms Were Machined to the Extreme Limits of Plus or Minus 0.01 In. the Crankshaft Would Be Considerably Out of Balance. Because of the Restrictions Placed on the Removal of the Correction Masses These Shafts Are Extremely Difficult to Balance and after an Exhaustive Investigation of the Problem, the Grinding Method Shown in Fig. 2 Was Adopted

we visited several plants that had installed balancing-machines. We found that the corrections were made either by drilling holes in the crank-arms or by planing-off stock from the corners of the crank-arms after the crankshaft had otherwise been machined completely. Both the six-cylinder and the eight-cylinder types of crankshaft are extremely difficult to balance because of the restrictions placed on the removal of the corrective masses. A crankshaft corrected by drilling was submitted to and was rejected immediately by the engineering department, because the holes tended to weaken the structure. Drilling disfigures such a shaft and gives the impression that it has been resorted to as an expedient. Further study showed that five possible methods of effecting balance remained. These are

(1) Varying the bore of the hole in the crankpin
(2) Using calibrated plugs in the crankpin bores
(3) Beveling the crank-arm opposite the end of the crankpins
(4) Removing uniform layers from the periphery of the crank-arm
(5) Removing uniform layers of metal from the flat side of the crank-arm

The first method was rejected because of its great expense and inconvenience. While in a certain sense it is convenient, the second method is subject to errors of fitting wrong plugs. The third method, that of beveling-off the corners of the crank-arms, was tried temporarily and worked well; but this process involves considerable skill and many trials on the part of the operator and, while this method was allowed, it was a slow and costly process in production. The fourth and fifth methods seemed the most promising and were, therefore, given further study.

At this point in the investigation it appeared that with eight different crank-throws the number of corrections would be very great and the method of balancing very complicated, since the unbalanced condition of the shaft might be any combination and have any location, particularly if the static and the dynamic unbalance needed to be corrected separately, because the corrections on the cheeks had to be components of the unbalanced forces.

It was then decided to select two arbitrary planes in

[1] M.S.A.E.—Assistant mechanical superintendent, Packard Motor Car Co., Detroit.

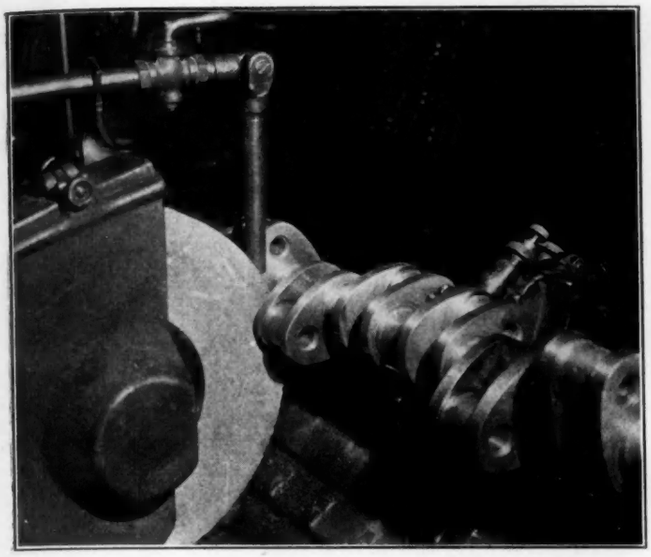

FIG. 2—CORRECTING UNBALANCE OF THE PACKARD CRANKSHAFT BY GRINDING THE SIDES OF THE TWO ARMS AT EACH END OF THE SHAFT

As a Result of the Investigation of This Subject It Was Decided To Select Two Arbitrary Planes in Which To Correct Any Unbalance. By Allowing Stock on the Sides of the Four Crank Arms, Two at Each End of the Crankshaft, the Unbalance Could Be Restricted to the Quadrant Bounded by These Arms and Corrections Made by Grinding

which to correct any unbalance in the crankshaft. Choosing an eight-cylinder type of crankshaft as being more difficult to balance than the six-cylinder type, it was found that, by allowing stock on the sides of the *A*, *B*, *C* and *D* crank-arms, the unbalance at each end could be restricted to the quadrant bounded by the two crank-arms at each end and that the corrections could be made by grinding the sides of these arms as shown in Fig. 2. The correction tables needed to determine the amount of stock to grind-off were then calculated. Fig. 3 shows the precision balancing-machine that measures directly the amount of unbalance in the two arbitrary planes selected.

The correction for unbalance in the crankshaft has thus been reduced to the simplest of operations and, with the aid of a chart that is easily understandable, it is necessary only for the balancing-machine operator to mark the amount to be removed on the sides of the crank-arms on which the grinding operations are to be performed. To facilitate the balancing operations further, the use of closer limits was studied. It was found that certain limits could be closed-in and that the amount of the out-of-balance condition could be reduced in this manner.

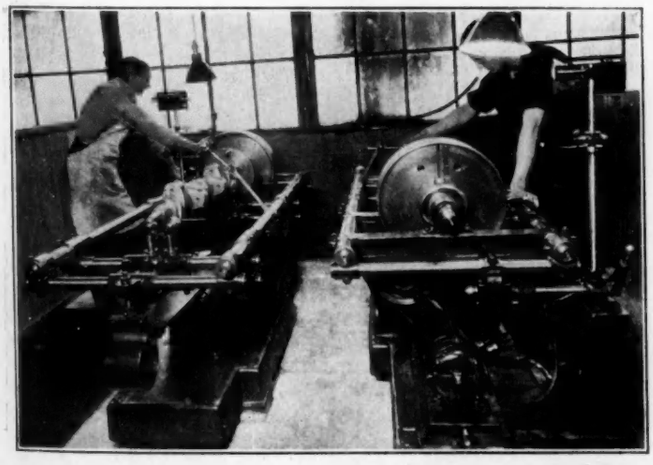

FIG. 3—THE BALANCING MACHINE THAT MEASURES DIRECTLY THE AMOUNT OF UNBALANCE IN THE TWO PLANES SELECTED ARBITRARILY

Since the Correction for Unbalance in the Crankshaft Has Been Reduced to the Simplest of Operations and an Easily Understood Chart Is Provided, It Is Only Necessary for the Balancing Machine Operator To Mark the Amount To Be Removed by Grinding from the Sides of the Crank Arms

FLYWHEELS

It was found by experiment that if put into perfect static balance a flywheel machined accurately all over would show very little dynamic unbalance, on account of its short length. The balancing-machine shown in Fig 4 has several admirable characteristics for correcting the unbalance in flywheels and was selected by us as a suitable machine for our work. After a series of tests and re-checks on other balancing equipment, it was demonstrated that by reading the indicator carefully, adjusting the correcting plates and making the corrections

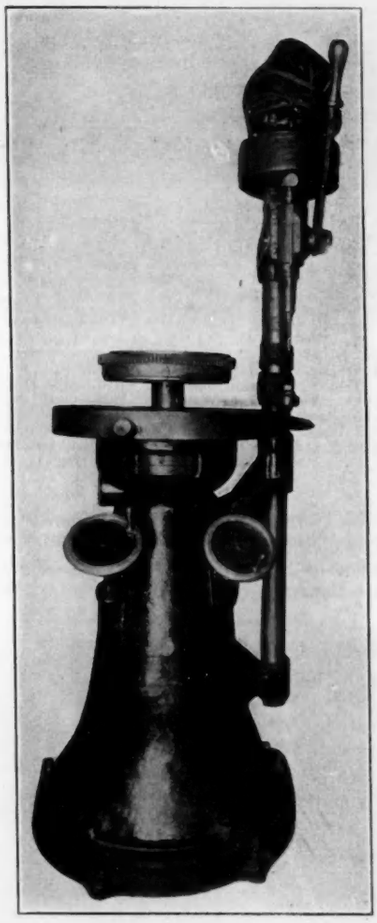

FIG. 4—VERTICAL BALANCING MACHINE USED FOR CORRECTING THE UNBALANCE IN FLYWHEELS

While the Machine Is Perhaps Not As Sensitive on Account of Its Bearing Structure, as Some of the Horizontal-Type Machines, It Nevertheless Is Possible To Make the Corrections with the Drilling Machine Attached without Removing the Part To Be Corrected from the Machine. After a Series of Tests and Rechecking on Other Balancing Equipment, It Was Demonstrated That by Carefully Reading the Indicator, Adjusting the Correcting Plates and Making the Corrections in Accordance with the Readings the Amount of Error Would Be Less than ¼ Oz-In.

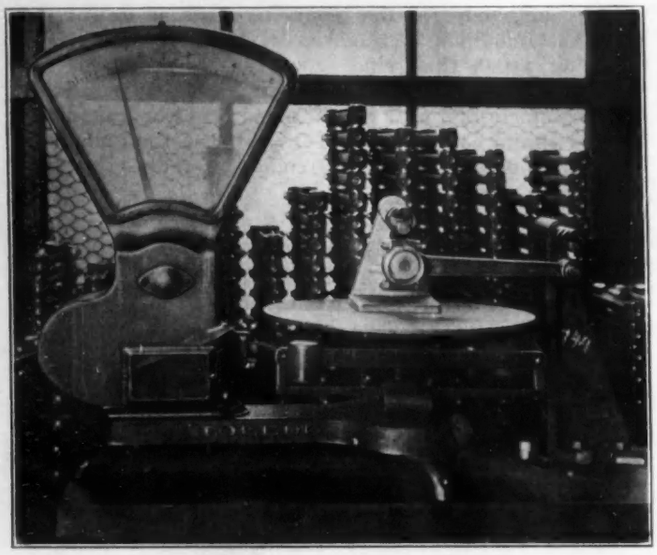

FIG. 5—SCALE AND FIXTURES USED IN BALANCING THE CONNECTING-RODS

The Connecting-Rods Are Selected in Sets Which When Ready To Assemble into the Engine Are Alike to within Plus or Minus ⅛ Oz. both for the Total Weight and the Center of Mass. After Weighing and Dividing the Rods into 32 Classes Based on a 4-Oz. Difference between the Lightest and the Heaviest Rods, They Are Further Classified by the Weight of the Crank-Pin End Only. For Doing This the Scale Is Mounted on a Surface Plate to Which Is Also Attached a Bracket To Support the Piston-Pin End of the Connecting-Rod. The Crankpin End of the Rod Is Supported by Another Bracket. Both Brackets Are Equipped with Knife-Edges from Which U-Shaped Members Are Suspended on Rings. The Upper Arms of the U Have Knife-Edges Bearihg on the Rings and the Lower Arms Are Made To Fit Loosely into the Crankpin and the Piston-Pin Holes of the Rod

in accordance with the readings, the amount of error would be less than ¼ oz-in. The machine is of the vertical type and, while perhaps not as sensitive on account of its bearing structure as some of the horizontal types of balancing-machine, it has a feature that appeals to the production man, as it is possible to make the corrections with the drilling machine attached without removing the part to be corrected from the machine.

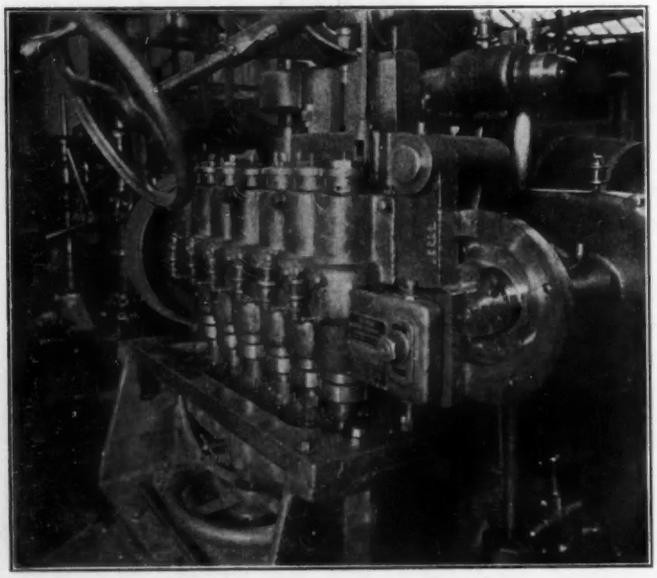

FIG. 6—SPECIAL MACHINE FOR PROFILING COMBUSTION-CHAMBERS

The Combustion-Chambers in the Detachable Heads of the Engines Are Completely Machined Like Their Neighbors in the Cylinder-Head, Thus Insuring Uniform Volume. Two Cuts Are Taken To Give a Smooth Surface Which Has Been Found To Deter the Formation of Carbon Deposits. The Machines Used for This Work Are of Special Design and Have Characteristics in Common with Automatic Multiple-Spindle Profiling-Machines, the Horizontal and the Transverse Feeds for the Cutters Being Actuated by Two Cams That Control the Contour of the Chambers. The Cutters Are of the End-Milling Type and Have a Special Form

CONNECTING-RODS

It is important to have connecting-rods balance. The connecting-rods for our engines are selected in sets. The rods of a set ready to assemble into the engine are alike within ± ⅛ oz. as to both total weight and center of mass. Fig. 5 shows the scale and the fixtures used in this connection. The rods are first weighed and classified for total weight and, as there is a difference of 4 oz. between the lightest and the heaviest rods, it is necessary to provide for 32 classes into which the rods are separated before proceeding with the next operation. This is to classify by the weight of the crankpin end only. The same limits, ± ⅛ oz., are allowed as for the preceding operation.

Special brackets were made and incorporated as units of a weighing scale, to make a fixture suitable for weighing the crankpin end of the rod. The scale is mounted on a surface-plate to which a bracket is attached also to support, off the scale, the piston-pin end of the connecting-rod. A bracket fastened to the scale platform supports the crankpin end of the rod. Both brackets are equipped with knife-edges, from which are suspended on rings certain U-shaped members. The upper arms of the U have knife-edges bearing on the rings, and the lower arms are made to fit loosely into the crankpin and the piston-pin holes of the connecting-rod.

IMPULSE BALANCE

Firing balance, that is, having the intensity of the impulses as nearly equal as possible, contributes greatly to smoothness of operation. The combustion-chambers in the detachable heads of both the six-cylinder and the eight-cylinder engines are completely machined like their neighbors in the head, assuring uniform volume. Two cuts are necessary to obtain the fine finish required, it having been proved conclusively that a smooth surface greatly deters the formation of carbon deposits. Fig. 6 shows a machine for profiling combustion-chambers. The machines used, of special design, were developed at our plant. They have characteristics in common with automatic multiple-spindle profiling-machines, the horizontal and transverse feeds for the cutters being actuated by two cams that control the contour of the chambers. The cutters are of special form and are of the end-milling type.

MAINTAINING BALANCE IN ASSEMBLY

A number of things can happen in assembling the engine which will offset all the careful effort spent in balancing the parts. To eliminate this, the pistons and the piston-pins are selected carefully as to both weight and fit. The fitting of the rings and the pins to the pistons and of the pistons to the cylinders requires extreme care; errors made at this stage of the assembly, such as bending the connecting-rod slightly or distorting the pistons, will result in a number of serious engine troubles, among which are a loss of compression with consequent varying of the explosion pressures, oil-pumping and scoring of the cylinder-walls and the piston. Any of these will cause excessive vibration with its resultant noises.

To prevent breaking the piston-rings and distorting the pistons and the connecting-rods when assembling the cylinder to the engine, a special fixture was made

which compresses the piston-rings and holds the pistons in alignment with the cylinder. Fig. 7 shows the machine during the first step of assembling the cylinder-block to the engine. The cylinder-block assembly is clamped to and supported by a fixture that slides upon the cylindrical posts shown in the background. Vertical movement of the fixture is controlled by an air-hoist. Split clamps are placed around each pair of pistons to tie them together as a rigid unit and prevent distortion of the connecting-rods. The clamps also serve to close the piston-rings as they slip into the cylinder bore. One of the clamps is shown open on the right-hand pair of pistons. As the operator opens the valve controlling the air-hoist, the cylinder-block is lowered and guided accurately into place until all the pistons have passed into the cylinders. The three piston-clamps are removed just before the cylinder-block reaches its seat on the upper face of the crankcase.

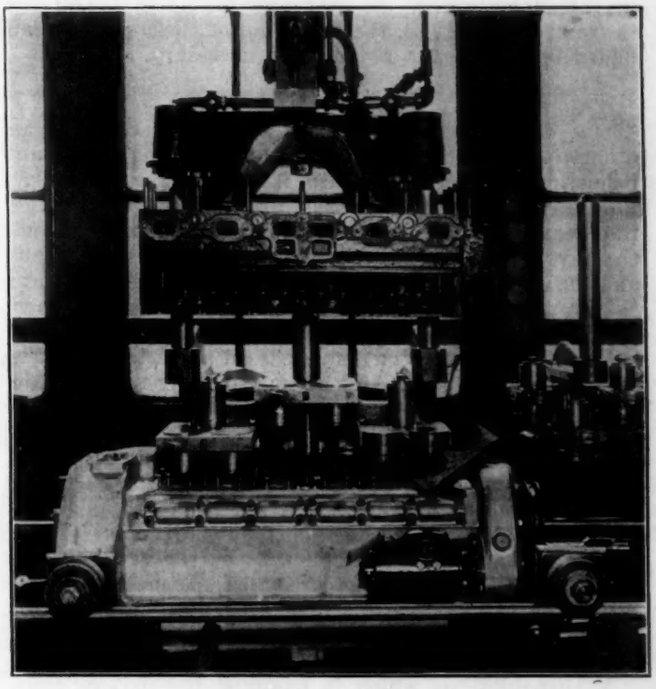

FIG. 7—PACKARD CYLINDER AND CRANKCASE ASSEMBLY FIXTURE

The Cylinder-Block Assembly Is Clamped to and Supported by a Fixture Which Slides upon the Cylindrical Posts Shown in the Background. Vertical Movement of the Fixture Is Controlled by an Air-Hoist. Split Clamps Are Placed around Each Pair of Pistons To Tie Them Together as a Rigid Unit and Prevent Distortion of the Connecting-Rods. The Clamps Also Serve To Close the Piston-Rings as They Slip into the Cylinder Bore. One of the Clamps Is Shown Open on the Right-Hand Pair of Pistons. As the Operator Opens the Valve Controlling the Air-Hoist, the Cylinder-Block Is Lowered and Guided Accurately into Place Until All of the Pistons Have Passed into the Cylinders. The Three Piston Clamps Are Removed Just Before the Cylinder-Block Reaches Its Seat on the Upper Face of the Crankcase

CLUTCH BALANCE

If the clutch is of the multiple-disc type, clutch noises are due mainly to the shifting of any of the plates that may be slightly out-of-balance. It is almost impossible to detect the unbalance until this unit has been assembled completely to the transmission and tested on the running-in stand; even then about the only correction that can be made is to dismantle the clutch from the transmission and try another. Certain devices for meshing snugly the teeth of the outer clutch-plate farthest from the spring-backing plate have been resorted to by many manufacturers, and nearly all of them function to the extent of eliminating a pounding noise that is usually heard when the engine is idling or when the speed-gears are shifted.

The outer and inner drums and the backing-plate of our clutch are balanced accurately on parallel balancing-ways. The gears and the shafts of the transmission are

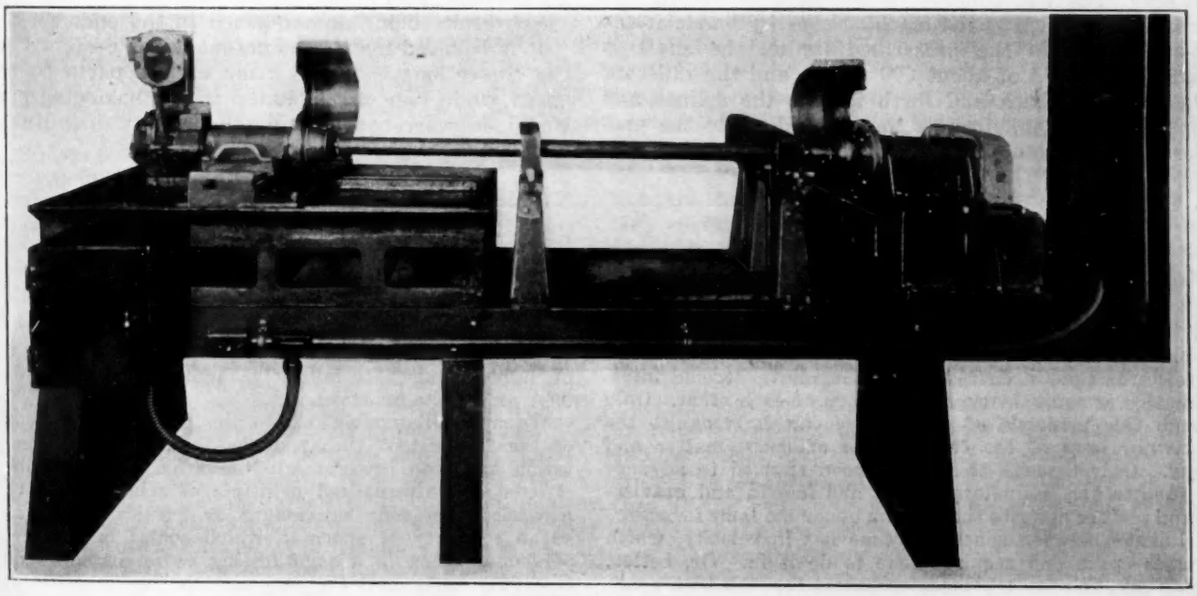

FIG. 8—MACHINE USED FOR DETECTING UNBALANCE IN PROPELLER-SHAFT UNITS

The Headstock, in Which the Driving-Plate Spindle Is Mounted on the Same Size Bearings and with the Same Spacing As Is Used in a Rear-Axle, Is Bolted Rigidly to the Horizontal Bed of the Machine. The Tailstock Is Mounted on a Transverse Slide That Allows the Propeller-Shaft To Be Moved Through Approximately the Same Angular Range as Would Be Encountered in Service on the Road. At the Extreme Outer End of the Tailstock Spindle a Speedometer Registering Miles per Hour Is Mounted and between the Headstock and the Tailstock Is Mounted a Bracket for Holding a Dial Indicator That Registers the Amount of Run-Out of the Propeller-Shaft. First the Amount of Run-Out Is Noted by Turning the Machine Over by Hand; If This Does Not Exceed the Prescribed Limits, the Shaft Is Rotated at Approximately 600 R.P.M. and the Tailstock Slide Worked Back and Forth To Free the Splines and the Trunnions. The Tailstock Is Then Locked while the Propeller-Shaft Is Rotated Through the Full Range of the Speedometer. Any Unbalance Manifests Itself through a Disagreeable Buzzing Sound and a Clattering of the Tailstock when the Locking Handle Is Loosened

machined accurately all over and the teeth of all the gears are ground; so, the balancing of these parts as an added operation was not deemed necessary.

Propeller-Shafts

One of the great sources of annoying noises in an otherwise smooth-running car can be traced to an unbalanced propeller-shaft with its connecting universal-joints, causing vibrations that are transmitted through the gear-trains on either end. This sometimes leads the investigator to believe that the transmission gears and the axle gears are at fault, or he may be led to place the blame on the supporting bearings. It has been found sometimes that, even after selecting an engine, a transmission and an axle that have passed all tests for quietness, vibrations within the normal driving-range would still be present due to propeller-shaft unbalance when the assembly was installed in a car.

A testing-machine for detecting unbalance in propeller-shaft units was constructed at our plant. It certainly represents money well spent, for it revealed to us a condition that called for the immediate correction of the inaccuracies of this important unit by the vendors supplying it. Fig. 8 is a photograph of the machine used. While the idea of the machine in general is not new, certain features that were incorporated are worthy of description.

A headstock, in which is mounted the driving-plate spindle on bearings of the same size and spacing as are used in our rear-axle, is bolted rigidly to the horizontal bed of the machine. The tailstock is mounted on a transverse slide that allows the propeller-shaft to be moved through approximately the same angular range as would be encountered in service on the road. A speedometer that registers miles per hour is mounted at the outermost end of the tailstock spindle, and a bracket for holding a dial indicator to register the amount of run-out of the propeller-shaft is mounted between the head and the tailstock. The test consists of noting first the amount of run-out by turning the machine over by hand; if the run-out is within the prescribed limits, the shaft is rotated at a speed of about 600 r.p.m., and the tailstock slide is worked back and forth to free the splines and trunnions. The tailstock is then locked while the propeller-shaft is rotated through the full range of the speedometer. If any unbalance is present, it is manifested by a disagreeable buzzing sound and a clattering of the tailstock when the locking handle is loosened. All shafts are rejected that do not run smoothly when the tailstock is moved back and forth. We have not yet found a way to correct an unbalanced propeller-shaft satisfactorily, and the only recourse to date has been to send the rejected propeller-shafts and universal-joint units back to the vendor.

Nearly all makers of balancing equipment for motor cars seem to concentrate on the crankshaft as constituting the major problem to be solved for unbalance; but, as a matter of fact, the general trend in the design of crankshafts is to increase the number of main bearings and to machine the shaft all over, causing the crankshaft to become only one of the many other important parts that require balancing, such as flywheels, clutch parts and propeller-shafts.

It is true that these machines can be adapted to handle practically any rotating body within their particular range, but the greatest difficulty has been experienced in making the correction for the unbalance. Taking the flywheel as an example, to correct for unbalance on the horizontal type of machine having roller supports, which is the predominating type, it is necessary, first, to attach an arbor to the flywheel and place it in the balancing-machine; second, to make the determination; third, to dismantle the arbor, unless a multiplicity of arbors is provided for; fourth, to make the correction; and fifth, to assemble the flywheel, with the arbor again for a check unless a chance is taken that the operator who made the corrections did his work right. We know that if the operator is not checked, he will often make a mistake. All the operations enumerated consume considerable time and require a good deal of equipment. If the costs of making the corrections are checked carefully, it will be found in many cases that it would be advantageous to work to closer machining-tolerances to permit the elimination of the balancing operations, the same results being accomplished in the end.

It is believed that balancing-machines designed so that the corrections could be made on the parts to be balanced while they are mounted in the balancing-machine would decrease considerably the cost of manufacturing the parts.

RELATIVITY

THE new relativity, with Einstein as its protagonist, has brought to likeness, or mutual conformity, mass, matter and electromagnetic energy, until they have become interchangeable or equivalent manifestations of each other. Only through this principle of equivalence can it recognize the old law or laws of the conservation of mass, matter and energy. Only through this has it been enabled to advance still further and assimilate weight and inertia and gravitation and posit or describe their action under the same formula.

A linkage between space and time lies in velocity, which traverses space and requires time to do it in. Or, better, we may say, velocity traverses or passes through both space and time. In the new scheme of relativity, the velocity of an object is the expression of the time required to traverse a space, relatively to the observer, or of the time required for the observer to traverse a space relatively to the object, and with the seconds of his chronometer shortened according to the velocity of his motion. Since the object, or person, in motion is also held to shorten in proportion to the velocity, time and space diminish together as the velocity of the observer increases and lengthen with the lessening of his speed. The velocity of a body can never pass the velocity of light because its infinitely increased mass would then offer an infinite resistance.

We are still moving within the purview and deductions of the "restricted" theory of relativity. Only when gravitation has been brought into the same fold will the unrestricted or universalized principle of relativity be reached. Einstein concluded that weight or gravity is not a force, but a property of space in which bodies move freely. A person standing in a cage resting at an immense distance from the earth and the sun and the stars would feel no weight or gravitation. But if his cage were drawn aloft at a speed constantly accelerated at the rate of the constant acceleration of a falling object near the earth, he would have the same sense of weight that he had on earth. The weight or gravitation of a body cannot be distinguished from its inertia.

Curvature of our standard of straightness is now acknowledged.—H. O. Taylor.

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Commercial Aviation in 1923

By EDWARD P. WARNER[1]

METROPOLITAN SECTION PAPER

A COMPARISON of the air-maps of the world for 1920 and 1923 shows that the principal change that has taken place during this period has been the consolidation of numerous short airlines into long ones. The saying that airlines of greater length than from 250 to 350 miles cannot be operated successfully still holds good, but the trend has been toward connecting or combining several routes of this length into one of much greater length. Most terminals are so far from the centers of the cities served by them that much valuable time is lost in going to and from the flying-fields, the average speed of the journey being correspondingly reduced. In Europe most of the airlines have been made international for political reasons and because of the saving of time that would ordinarily be lost at the customs frontiers. On the lines between England and the Continent in 1920 approximately 50 per cent of the passengers were Americans. On many other lines the passenger traffic was almost negligible, the lines being able to operate only because they were subsidized by their respective governments.

Recent technical developments abroad have been slight, the principal ones having reference largely to the comfort and the convenience of passengers; those in America have been marked by the extensive use of the seaplane for transporting both passengers and express. Advances in this Country have been due mainly to the successful operation of the Air Mail Service, which has made a remarkable record for efficiency in all sorts of weather and under adverse conditions. But although the service has been most efficient there have been but few passengers. This has been attributed to the cost and to the irreglarity of the service, but these reasons are shown to carry little weight.

Although statistics show that a fatality occurs in the ratio of 1 to every 1,250,000 passenger-miles flown, which would indicate that the odds are 2 to 1 against its occurring in a machine flying 12,000 miles per year for 40 years, there is an instinctive feeling of danger in the minds of the public. Persons are free to admit that aviation is the coming means of transportation for others but not for themselves. This feeling is enhanced by newspaper stories of the thrills and the suffering of pilots who have attempted to break records and by descriptions of the stunts performed in exhibition flying. Safety is more important to most persons than thrills.

European methods of impressing passengers with the extra-hazardous nature of the venture and of disclaiming responsibility for accidents do not tend toward making riding in airplanes more attractive. Foreign companies are independent because of subsidies and do not encourage passenger traffic. Subsidies are unfortunate in many ways because of the obligations that are required in return and because of the restrictions that are imposed, which retard proper development.

Bulk of traffic inspires confidence; the rails of a railroad are a constant reminder of stability. The trips of an airplane, on the other hand, do not give an impression of continuity of service.

Large-scale operation cannot be secured until the necessary money can be obtained to finance it and, in turn, the requisite amount of money cannot be obtained until the financial interests are convinced by the volume of traffic that the venture will be successful. The most obvious method of increasing the confidence of the public would be through extensions of the Air Mail Service. It is suggested that a large number of lines should be installed and radiate from a single city rather than be spread over large sections of country. After stability has been thoroughly well demonstrated and volume of traffic has been secured in one locality, the service should be extended to other sections.

Two recommendations are made for obtaining greater confidence: (*a*) that those interested in commercial flying devote themselves to a study of public psychology and (*b*) that a display of energy, vision and courage on their own part would undoubtedly lead to the expenditure of the money necessary to lay a firm foundation for a profitable structure.

WHEN we attempt to make an examination of the development of the last 22 months, we find that there has been so little change that it affords little scope for comment; the lines laid down in 1920 and 1921 have been followed without material variation, except in a very few respects, which are worthy of emphasis. If we compare the air-map of the world in 1920 with that in 1923, the most striking difference is to be found in the abandonment of the short routes that were so numerous in the earlier year and their amalgamation into longer international airlines, each of which covers a much greater distance than any single commercial route laid out 2 years ago.

This, at first sight, seems to be a direct contradiction to what we used to lay down as one of the first principles of the utilization of the airplane. It was said truthfully that an airplane could not be economically and efficiently operated over single journeys of more than 250, or at most 300 or 350, miles in length. That remains true but, in order that the full usefulness of the airplane may be realized, it is necessary that a number of such stages be combined and that the actual route as a whole be very long, since most of the terminals used for airplane operation are rather far from the centers of the cities that they serve. In many cases it takes over an hour to get from the flying-field to the center of the city to which it belongs; hence, on a journey of only 200 or 300 miles in length, the average speed is greatly decreased by the time lost in an automobile, railroad or street-car journey at the end.

Although the loss at the terminals is one of the principal reasons for superseding short lines by very long ones, it is not by any means the only reason. We see another cause very clearly when we observe that almost every line operating in Europe is international in extent, that all the French lines which were confined within the borders of the French Republic have been abandoned and have been replaced by, or have at most become a part of, some route that extends from Paris, or some other French city, into a foreign country, or from France to one of the French colonies. The same thing is true elsewhere. In Germany, nine major airlines were started last spring, and all but one had one of their termini outside the German Republic.

The motive for seeking international traffic by air is largely political, although there is some reason for run-

[1] M.S.A.E.—Associate professor of aeronautical engineering, Massachusetts Institute of Technology, Cambridge, Mass.

ning international lines in the time and trouble saved to passengers at customs frontiers. It is hardly fair, as a result, to take the data of operation directly from present-day lines as a whole and say that they represent the ultimate that can be achieved, or to compare them even with the results of airlines running without government assistance that have to stand on their own feet. All the European airlines with one or two exceptions are directly subsidized by the government and, generally speaking, where direct government subsidy comes in, and particularly where a political motive in the choice of routes comes in at the door, business efficiency flies out at the window. So the costs of operation are rather high. The cost to the passenger, however, has been kept down by the very generous subsidy policy of some of the European states.

There has been a certain increase in the traffic by air since 1920 but it is a very much smaller increase than might fairly have been expected 2 or 3 years ago. In fact, the maximum seems to have been approached in many cases. The traffic this year has been little if any greater than last year. Complete figures for the summer of 1923 are not yet available on the same basis as those for 1922, but the traffic of 1922 was only a little greater than that of 1921, when there had been a considerable increase from the preceding year, and almost all that traffic is being concentrated on a very few lines. In the last year, for example, up to March 31, 1923, approximately 13,000 passengers were carried between England and the continent of Europe by air, with a maximum of 2700 in 1 summer month. But it is a significant fact for Americans that more than 50 per cent of the total business was done with American tourists; that the European business man or, for that matter, the European bound on any other errand than that of pleasure, contributes less than 30 per cent of the total traffic, assuming that only 15 per cent more in addition to the 55 per cent of American tourists is European tourist traffic. On many of the lines, the traffic, business, tourist, or any other, is almost negligible, and the lines continue to operate only by virtue of the subsidy. In one notorious case a certain line operates over a distance of about 1200 miles, on which 95 per cent of the gross receipts during the last year came directly from government subsidy and 5 per cent from passengers, express and mail.

Technical Developments Lacking

There has been no very notable technical development. A comparison of the airplanes used now with those used 2 years ago is rather disappointing, although there has, to be sure, been some improvement. Airplanes are certainly more comfortable and more convenient for passengers now than at an earlier date, but the change has been much less than the public had a right to expect. In America, despite the much smaller use of commercial aircraft for passenger transport, the technical development, at least, has been on the whole very much more important than in Europe, by virtue of the achievements of the Air-Mail Service. No contribution to the commercial operation of airplanes since 1920, or for that matter at any other time, has been so great as that made by the Air-Mail Service in the last 2 years, in showing that it is possible to fly in any and all weathers, with a record of efficiency and a percentage of operation so close to perfection that the difference, under the conditions of the more favorable months of the year at least, is hardly perceptible; and still more particularly in its recent achievement in flying both by day and by night over the transcontinental route, covering the Chicago-Cheyenne stage by night, so that the air-mail went through, without any delay or break, from New York City to San Francisco.

American development also has been marked by the extended use of the seaplane for passenger and express transport. I shall not say much about that nor try to give figures, but I wish to speak of the difficulties in the way of continued expansion and the obstacles that lie before the commercial use of airplanes today. I do not wish to be interpreted as offering counsels of pessimism. No one believes more thoroughly in the future of the commercial airplane, in the possibility of the commercial use of the airplane, and in the greatness of the economic service that it can render to America, than I do, and no one is more ready to stake his future on that development and on a constant increase of the commercial use of aircraft than I am. But I believe that it will not do us any good to continue saying indefinitely that everything is lovely, to continue the policy of optimism that has sometimes prevailed to a rather excessive degree. If there are obstacles in the way, we ought to face them; we ought to concentrate our efforts on removing them, rather than try to deceive ourselves, dodge the difficulties and refuse to admit that they exist.

Why are there no more passengers by air today, practically speaking, than there were in 1921 in Europe, where there has been far more of that particular development than here? And why is there so little interest in and so little sympathy for air transport in the United States?

Obstacles to Passenger Traffic

The principal obstacle in the way of passenger-carrying by air is that passengers do not come forward to ride, but that simply shifts the burden of the question. We wish to know why the public does not turn to the airplane, and why it is that we do not get the business that we have a right to expect when we see the saving of time that can be made and the record that has been shown by the Air Mail Service and by various other enterprises in actual operation. There are various possible explanations.

One that is often brought forward is the relatively high cost of travel by air. Personally, I do not believe that to be a factor. It is possible to travel by air in various parts of Europe for a price per passenger-mile that is less than the cost of railroad travel in this Country, or for that matter in some of the European countries. In some of the countries of Central Europe, under present economic conditions, it is possible to travel by air for so little that it seems foolish to translate the amount into American money. I do not know what the German air-lines are getting now, with the mark at something like 4,000,000,000,000 to the dollar, but when I was in Germany last it cost about 2 cents per passenger-mile to fly from Berlin to Hamburg, or about $3.50 for the journey; considerably less than any railroad rate in any country with an exchange anywhere near normal. Even when the fare is thus reduced by the depression of the currency, or by a very generous government subsidy, or otherwise, there does not seem to be any great and sudden increase in the passenger traffic. It has been pointed out to me that when you offer free rides in airplanes, you never have difficulty in getting people to accept them. It is very easy to get people to go up in an airplane over a field, but there seems to be a marked reluctance to depend upon an airplane for ordinary travel between two distant cities, no matter how low the fare may be set. It is my belief

that we can lay aside the economic factor as relatively unimportant.

A second possible element is the irregularity that sometimes features the service. Admitting that the service is likely to be irregular, that the percentage of completed trips is likely to be about 80 or 85, which, of course, is very poor, under favorable weather conditions and on bad routes the Air Mail Service has shown what can be done with properly maintained airplanes and with properly chosen pilots who are familiar with the territory over which they fly; and it can be done without any increase in hazard, because the casualty record of the Air Mail Service, as you know, has been extraordinarily good.

A third possible cause of the reluctance to use the airplane is the supposed danger of air travel, and there, it seems to me, is the thing that is really keeping people from traveling today. You will note that I say "supposed danger," because I do not believe for a minute, and none of you here who have anything to do with the operation of airplanes and are familiar with the amount of flying that is done without any accident believes for a minute, that the danger is nearly what the public is disposed to consider it to be.

The statistics are more or less familiar; we have heard them in the past; they change form a little from time to time. In general, they show a gradual improvement and will continue, of course, to show improvement as airplane designs and maintenance improve, and as we learn more about the operation of commercial airplanes and about their care. During the last 2½ years the British airlines have flown about 5,000,000 passenger-miles with but one fatal accident, which happened between Manchester and London some months ago.

One airline on the Continent has flown something over 1,000,000 airplane-miles without a single accident involving serious injury to a passenger. That is a record which can be duplicated or nearly duplicated by others. Some have not flown so far, but several have perfectly clear records. In general, it may be said that it has been shown to be possible to fly at least 1,250,000 passenger-miles for every fatality. That is a fair average, and it has been considerably beaten in some cases. It means that if an airplane were used 12,000 miles per year for 40 years, that the odds would be 2 to 1 against an accident. Within 40 years that rate, undoubtedly, will be much lower than it is now. However, to prove by statistics that flying is safe does not suffice. To prove that the danger is relatively low, that if not fully as low as in some other means of transportation it is at least not great enough to be a decisive factor, does not in general avail. You can quote statistics for an indefinite length of time to most persons and you will leave them perfectly cold so long as they themselves have had no first-hand experience with the airplane or are not in direct and continuous touch with someone who is engaged in flying. Statistics do not avail because the public feeling with which we must contend goes rather too deep to be met with figures; it is an instinct for which no reason can be given by those who hold it.

Viewpoint of the Public

I have made it a point for several years, whenever I have been with a group of persons whom I did not know and who did not know that I had any connection with aviation, to try to turn the conversation to commercial flying and its future possibilities. Those who have no direct knowledge of or interest in the subject are always ready to agree that the airplane will be the passenger vehicle of the future. In fact, some go much farther than we who are in flying would wish to go; they talk freely and blithely about the replacement of railroads and automobiles with airplanes. But there always seems to be a modifying clause when one of these highly optimistic statements is made. My informant habitually says: "Within 20 years everyone will be flying, without doubt, *except me*." They all hesitate to admit that they themselves will come forward and ride by air. That is what we are "up against."

We must show them that the airplane is so useful that they cannot get along without it; that it is a commonplace vehicle, not nearly as common as some other means of transportation, but just as prosaic and practical; that there is nothing magical about the airplane; and that there is nothing mysterious about its use in the ordinary operations of commerce.

In the first place, the man whom we want to persuade to fly in a commercial airplane thinks it must be dangerous. He cannot give any reason why it should be, and he is perfectly willing to admit that the figures you quote, to show that it is not, are doubtless correct; but he has a feeling that there is something fundamentally immoral about getting his feet off the ground. And, in the second place, most of the stories about aviation that he sees in the newspapers relate how somebody went up in an airplane to a height of 40,000 ft. and came down half-frozen and half-conscious, or how somebody else flew 270 m.p.h. or thereabouts and made the turns with such violence that he became dizzy and temporarily blind, or how some other fellow flew upside-down for a protracted period. He does not think that any of those things sounds as if it would be much fun, and I do not know that we can blame him.

The second objection I mentioned, the objection founded on the kind of exhibition flying that is being put before the public and on the kind of newspaper story that gets before the public, seems to me to be a very important matter. Many of you are connected with the automotive industry in New York City. I imagine that it would not have been particularly conducive to your prosperity or helpful to the automobile business if, in the early days when the automobile was first trying to get a foothold, all the sales talk and all the newspaper stories about automobiles had been confined to detailed accounts of the more lurid and sensational incidents that can happen during a road race. You would not have tried to sell a car to an ordinary human being by telling him that it had been shown in the last Vanderbilt Cup race that it was possible to skid around a rather sharp turn at 60 m.p.h. He had no desire to do it and it certainly would have scared him away.

That is exactly what we are doing in the case of the airplane and we have only ourselves to blame. If we bring the airplane forward primarily as a thrill producer, we cannot expect that it will be generally accepted as a safe and sane vehicle for ordinary human beings. It cannot be known at the same time as a vehicle for the performing of circus acrobatics and as a vehicle for the safe and sane transport of ordinary people. The two things do not mix. The stunting of airplanes is a military necessity, and the skill and the courage that it requires must, and do very properly, command the greatest admiration, but the existence of aerial acrobatics and of stunting is a veritable curse to the commercial use of aircraft.

Safety versus Stunting

I heard a great many people say, after seeing the Shenandoah flying overhead, or seeing her on the ground,

that she looked like an aircraft in which they would like to ride. I think that one reason the airship commands confidence at sight from many of those who have no connection at all with the aeronautic industry is that the airship moves only in a normal path and that there is no known way to stunt a rigid airship.

While the technical debt of those who seek to use the airplane for commercial purposes to the military necessity of 1914 to 1918 is very great, and the development of airplane design today would be far inferior to what it actually is if it had not been for the military requirements that forced aeronautic research and the energetic prosecution of design studies, we have derived from the military use of aircraft a certain number of difficulties. We would be in a much better position today to attract the public to the use of the airplane if the possibility of tilting the path of the airplane more than 30 deg. from the horizontal in any direction had never been discovered.

This is worth dwelling upon because it does affect a great many people. I have been at a number of flying meets where there have been exhibitions of aerial acrobatics of various sorts. I do not mean wing-walking, but acrobatics performed with the airplane. I have always heard the spectators at the meet express great admiration for the skill of the pilot, but I have never heard any of them express a fervent desire to be with him the next time he did his stunt, or indeed to be in an airplane under any conditions. We must remember that if sensational flying continues to form an important part of supposedly commercial, civilian exhibitions, attention will center upon it.

We have had recently a number of excellent illustrations of the regrettable fact that achievements in keeping to a schedule are regarded as very prosaic and of little news-value. The Air Mail Service has been operating for more than 5 years. It has been operating, as is too little known, with almost perfect regularity about 2,000,000 miles a year for the last 3 years, once each way each day over every part of the route from New York City to San Francisco. Yet in August, 1923, at the time the night-flying experiments were being made, I saw a large headline on the first page of the newspaper that has the largest circulation in one of the greatest cities of the United States, "Air Mail Now An Actual Fact." If the 5 years of flying without any trouble had gone completely out of the minds of the editors and of the make-up staff of that paper, how can we expect it to create a lasting impression on the minds of those who are not particularly concerned with flying or with writing the news about it, but have continually put before them the news of more sensational accomplishments? It is very easy to forget all that has been done without trouble and without sensational new developments.

We had another illustration when the Boston Air-Port was opened in September, 1923. It was agreed that it would be very undesirable from the standpoint of the future of commercial aviation in New England to have any aerial acrobatics performed, and we did our utmost to discourage it. Two of the pilots we did not reach, and so failed to ask them to refrain from stunting. One of them went up and did a few loops, then the other added a spin and two or three turns. Most of the Boston papers wrote their stories primarily around the 2 min. of mild stunting, giving hardly one-quarter of the space to the extraordinary record of regularity by the Army, Navy and privately owned airplanes. That indicates one reason people are afraid to travel by air. It is a thing we must overcome. The fear unfortunately is being intensified in many cases, and its bad effects are being augmented by business methods on the part of some of the airlines that would insure bankruptcy to any enterprise in the world not directly subsidized by a government.

European Business Methods

I have in mind particularly the practice that has been followed by some of the European airlines, which get so large a subsidy that they can afford to operate and make a profit if they carry no passengers at all, of forcing on every passenger a set of conditions which suggest to him inevitably that he is embarking on an extra-hazardous venture, nearly scare him to death before he takes passage and suggest to him that the company regards his presence in the airplane as a nuisance hardly to be tolerated. I have here a copy of the agreement printed on every ticket sold by one passenger-line operating between two European countries. It fills about two typewritten pages, but I shall mention only a few of the more significant items. Some of these things, of course, are essential, but as a whole they look rather bad to an inexperienced passenger.

> The company's time table is only approximate. The company reserves the right to modify in any manner desired the day and the hour of the departure of the airplanes, and the passengers have no redress as a result of such changes.
>
> Neither the company nor any of its agents assumes any responsibility for delay, or interruption, or termination of the journey. The passengers will be responsible for the payment of all expenses to them resulting from such happenings and all their indirect consequences.
>
> The company and its agents deny all responsibility for accidents, losses, delays, or injuries of any sort whatever, which may occur to the passengers or to their property during flights of the company's airplanes, whether they arise from fog, wind, forced landings, changes of route, changes of airplane used, strikes, fire, theft, or from any other mishap connected with aerial navigation, whether occurring while taking-off, while on the ground or while in full flight. The company will not be in any way responsible for the mistakes or the negligence of its pilots or of any other persons on board the airplanes.

That does not seem to be the best way to encourage commercial flying. If we cannot get along without that, we do not deserve to get along at all. Commercial flying will have no place until we can dispense with at least part of that agreement. I think we can dispense with a large part of it at the present time.

Advantages and Disadvantages of a Subsidy

What are the possible remedies for this rather unfortunate situation? Of course, the first and the most obvious thing would be to get Government support. That is worth alluding to as a possibility at least. Every country in the world, except the United States, seems to have given a subsidy for the commercial operation of aircraft. But, personally, I think that the results of a subsidy would be very unfortunate in many ways and, since I know the feeling is wide-spread that all the people who are interested in commercial flying in this Country are conspirators hatching a deep-dyed plan to get a subsidy from an unwilling Congress, I want to go on record, and I think most of you agree with me, as saying that personally I have no expectation of seeing a subsidy in this Country. I have no desire to see a subsidy and am very doubtful whether, in the long run, it would be a good thing here, as I am very doubtful

whether in the long run it will be a good thing in many of the countries that have already adopted it. The country that gives a subsidy intends to get something in return. The first thing it intends to get is the possibility of using the airplane for military purposes. The result is that it puts a damper on all changes from military to commercial design. Commercial design in some instances in some countries is being absolutely paralyzed by the necessity for complying with rigid subsidy requirements. The subsidy also, where it is excessively generous, is obviously capable of stifling the incentive of the company that operates the line. Take the case of a company drawing 95 per cent of its gross receipts from the government directly and making a profit. What incentive is there for it to advertise for business? Why should it wish to carry passengers? Why should it not regard passengers as a nuisance? All it has to do is to carry gasoline, fly the route and collect its pay. In the long run, a subsidy would be more of a handicap than an advantage. But, to get along without it, it is essential that airplanes should be operated on a far larger scale than they have been operated up to the present time.

Although in one sense it is a rather reckless statement, in another sense it is safe to say that there is no possible manner of either proving or disproving it. I have hazarded a speculation that it would be easier to get passengers for a line operating, let us say, 10 airplanes a day between two cities, after the line had been running for 6 months or a year, than it would be to get passengers for a similar line operating one airplane a day, or one a week, between the same two cities. Bulk of traffic in itself inspires confidence. The railroads have a great advantage over airplanes in that respect, because when a railroad is built the rails "stay put." They remind the people in the neighborhood of the existence of the enterprise and of its essential solidity, whereas the airplane flies overhead and is gone in a few seconds; another one comes along the next day or the next week, or some other time; meanwhile the passing of the last one has been substantially forgotten. You do not get the impression of continuity of operation. In order that general public confidence may be commanded, it is almost essential that there be operation on a reasonably large scale, to say nothing of the economic necessity for operating on such a scale in order that the cost of ground organization, reduced to a passenger-mile basis, may not become excessive.

To keep a large staff of mechanics, ground engineers, and other employees waiting at each of the three or four airdromes to receive one three-passenger airplane each day seems somewhat wasteful, to say the least.

Value of Large-Scale Operation

The railroad offers an example of the value of large-scale operation and of the arousing of public confidence by the very fact of the largeness of the enterprise.

The development of the automobile industry has afforded another instance. As you will all recall, the automobile industry progressed rather slowly for several years after the first cars were put on the market; then suddenly it came with a jump and the sales of the most popularly used make of car at that time, about 20 years ago, jumped from about 100 to about 1000 cars in a single year, when the agent in New York City undertook to sell a number very much in excess of anything he had handled before and tried to stimulate public interest on a very much larger scale than anyone had previously dreamed of attempting.

I may be wrong in my figures, for I am quoting them at second hand, but I believe that we shall see something of that sort in the airplane industry if we can once get large-scale operation. We are, of course, working around in a vicious circle. We cannot get large-scale operation unless someone will put the money in and unless passengers will ride and pay their fares; and passengers will not ride unless they are stimulated to do so by seeing airplanes operate and by having kept continually before them the reality of commercial flying and the importance of the service that it can render.

There are several possibilities, however, of securing that large-scale development, one of which is obvious and lies before us in the extension of the air mail. We have seen what the air mail has done when operated directly by the Government. If contracts are let for carrying mail by air between various cities of this Country, we at once provide for a certain amount of operation, we provide for covering at least a certain part of the cost of operation, whether passengers come forward or not, and we are enabled to keep the airplanes going on mail business while waiting for passengers to offer themselves.

The most important thing the Government can do, aside from laying-out air-ports and air-ways, in stimulating commercial aviation, is to provide for an extension of the air mail. It seems to me very desirable that at first there should be a high degree of concentration of these operations in one part of the Country, because we must show the public considerable flying to give the impression of the stability of commercial aeronautics, the necessity for which I have tried to emphasize. And the only way to show much flying is either to have one route operated very intensively or to have a number of routes operated from one point. I think much better results would be accomplished by running airlines, say from New York City to a dozen different points, than by trying to spread out the same amount of flying over the whole United States, because there is a distinct tendency to accept flying as an ordinary business utility where it has been in use long enough and intensively enough. The public indifference will be ultimately overcome, and we can then turn to similarly intensive efforts elsewhere.

In Great Britain and in parts of the European continent at the present time, the London-Paris airline is coming to be accepted as commonplace in an increasing degree after 4 years of operation. The regularity of the passenger traffic and the seeming indifference to weather conditions and to the time of the year increase the desire to use the airplane for business rather than merely as a means of securing a new thrill.

The second possibility is that private enterprise may undertake the development of commercial flying. It would require a great sum of money, but it seems inevitable, since the service to be rendered by the airplane is as great as it is, that the profit to be reaped ultimately would be commensurate with the initial expenditure; and what we need at the present time, more than anything else, is to "sell" aviation to the business community to such an extent that some body of men of sufficient financial strength will undertake to develop commercial flying and accept the financial hazard involved in return for an advantageous position when the tide turns and the full utility of the airplane begins to be realized.

The public is not taking to flying as we have a right to expect that it should, but there is hope that it will do so on two conditions: First, that those of us who are trying to develop commercial flying will add to our tech-

nical studies and to our endeavors to improve the airplanes used, a study of public psychology, and endeavor to convince the public of the real and undoubted merits of the airplanes and the airlines that are now in operation or that could now be operated. We must do that by presenting the facts as they actually exist at the present time. There has been considerable of such presentation of facts in various forms. We shall not accomplish anything, however, by circulating propaganda, in the more unpleasant sense of that phrase, for commercial flying. Statements that the airplane is now safer than the railroad are obviously so contrary to the facts that they carry on the face a conviction of the untrustworthiness of any statement that comes from the same source, and we should be content to state the facts as they actually stand. The second condition is that we, and the business community as a whole, shall emulate the pioneers of railroad transportation in the United States and show some of the energy, vision and courage that will lead to the expending of the money necessary to lay a firm foundation for a structure that will yield profits commensurate with the initial expenditure at a day not very far distant, but the exact distance of which cannot be predicted mathematically at this moment.

SUMMARY OF 5 YEARS' AIR MAIL OPERATION

THE accompanying tabulation is a statement of the performance of the Air Mail Service from May 15, 1918, the date when it was established by the inauguration of the route between New York City and the City of Washington, to Dec. 31, 1923. The New York City-City of Washington route, which as stated marked the establishment of the Air Mail, was discontinued on May 31, 1921. The Chicago-St. Louis route, which was inaugurated on Aug. 16, 1920, was discontinued on June 30, 1921, the same date on which service on the route between the Twin Cities, Minneapolis and St. Paul, and Chicago was suspended after 7 months' operation. The first leg of the Transcontinental Route between New York City and San Francisco, which is the only route now operated by the Post Office Department, was inaugurated on May 15, 1919, between Cleveland and Chicago. Service between New York City and Cleveland was inaugurated on July 1, 1919, between Chicago and Omaha on May 15, 1920, and between Omaha and San Francisco on Sept. 8, 1920. Two contract routes have been established between Seattle, Wash., and Victoria, B. C., and between New Orleans and Pilottown, La., to advance the delivery of foreign mail. At the present time the Post Office has no authority to establish routes for the carrying of mail on domestic or inland routes.

Year	Trips Scheduled	Trips Defaulted	Trips Attempted	Trips Uncompleted	Weather Encountered		Mileage Scheduled	Miles Traveled with Mail	Miles Ferry and Test	Total Miles Traveled	Performance Efficiency, Per Cent	Number of Letters Carried	Cost of Service	Causes of Forced Landings	
					Trips in Fog, Etc.	Trips Clear								Mechanical Trouble	Other Causes
1918	793	32	761	.....	258	535	87,042	81,898	20,650	102,548	94.09	4,720,240	$76,616.59	22	24
1919	1,761	87	1 674	.....	603	1,060	430,275	393,066	68,229	461,295	91.35	17,669,700	320,647.70	69	97
1920	4,941	1,009	3,932	328	1,614	2,318	1,107,266	864,128	184,316	1,048,444	78.04	30,975,500	979,997.25	445	385
1921	9,202	512	8,690	400	2,963	5,727	1,846,072	1,713,934	198,799	1,912,733	92.84	46,620,280	1,499,584.10	632	841
1922	8,291	292	7,999	145	2,935	5,064	1,643,657	1,570,089	186,714	1,756,803	95.52	60,487,880	1,417,374.82	206	367
1923	8,072	225	7,847	111	3,745	4,102	1,603,110	1,545,280	325,142	1,870,422	96.39	65,295,920	1,910,422.54	175	327
	33,060	2,157	30,903	984	12,118	18,806	6,717,422	6,168,395	983,850	7,152,245	91.83	225,769,520	$6,204,643.00	1,549	2,041

PETROLEUM PRODUCTS IN 1923

A NEW high record in gasoline production in the United States was attained in 1923, the Bureau of Mines, Department of the Interior, announces, 7,555,945,143 gal. having been produced, or an increase of 21.83 per cent over the 1922 gasoline output. The domestic demand amounted to 6,685,035,280 gal., while exports totaled 871,116,614 gal., which added to the domestic demand shows a total demand for the year amounting to 7,556,151,894 gal., an increase of 26.64 per cent over the total demand in 1922.

Gasoline stocks on hand Jan. 1, 1924, were 1,074,899,650 gal., an increase during the year of 191,106,789 gal., or 21.62 per cent. This increase in gasoline stocks, remarks the Bureau, compared favorably, from the refiners' point of view, with the increase of 50.80 per cent in stocks during 1922.

Imports of gasoline in 1923 were 191,313,540 gal., an increase of 207.91 per cent over the preceding year. The total new supply, production plus imports, in 1923 was 7,747,258,683 gal., or 23.67 per cent over the 1922 new supply. For the entire year the new supply exceeded the total demand by 2.53 per cent.

The indicated domestic demand for kerosene during the year was 1,492,535,909 gal., an increase of 1.96 per cent over the preceding year. Exports in 1923 were 854,554,951 gal., about 48,000,000 gal. less than in 1922.

The production of gas and fuel oils in 1923 was reported to the Bureau of Mines as 12,074,191,693 gal., an increase over the preceding year of 12.78 per cent. Imports were 516,022,937 gal. The total new supply amounted to 12,590,214,630 gal., an increase of 16.25 per cent over the preceding year. Domestic demand amounted to 10,978,285,596 gal., and exports were 1,401,622,173 gal., making a total demand of 12,379,907,769 gal., an increase of 14.03 per cent over 1922.

The 1923 output of lubricants was 1,097,368,222 gal., an increase of 12.12 per cent over the 1922 production. Imports during the year were 1,219,133 gal. The new supply was 1,098,587,355 gal., which exceeded by about 7,000,000 gal. the total demand of 1,091,537,072 gal., including exports of 351,599,047 gal., and domestic demand of 739,938,025 gal. Stocks of lubricants in the United States on Jan. 1, 1924, were 242,785,070 gal.—*Economic World.*

Applicants *for* Membership

The applications for membership received between Feb. 15, and March 15, 1924, are given below. The members of the Society are urged to send any pertinent information with regard to those listed which the Council should have for consideration prior to their election. It is requested that such communications from members be sent promptly.

AHLBERG, DANIEL F., draftsman and assistant superintendent, Clark Cutter Co., *Detroit.*

BACON, DAVID L., aeronautical engineer, National Advisory Committee for Aeronautics, Langley Field, *Hampton, Va.*

BEHNING, EDWARD F., engineer, gear division, Diamond State Fibre Co., *Bridgeport, Pa.*

BRASHEAR, W. R., service manager, Moon Motor Car Co., *St. Louis.*

BRUNSON, CAPT. M. V., Quartermaster Corps, *Camp Holabird, Md.*

BRYANT, JOHN W., JR., Wagner Electric Corporation, *St. Louis.*

BUNTING, FRANK E., student, Polytechnic Institute of Brooklyn, *Brooklyn, N. Y.*

BURKE, F. L., superintendent, Indiana Lamp Co., *Connersville, Ind.*

COVINGTON, THOMAS F., garage superintendent, American Oil Co., *Baltimore, Md.*

CRAVEN, DAVID S., service salesman, White Co., *San Francisco.*

EASTWOOD, GEORGE W., departmental manager, Arrol Johnston, Ltd., *Dumfries, Scotland.*

FLAHERTY, EDMUND M., director of sales, E. I. duPont de Nemours & Co., *Parlin, N. J.*

FRAUENTHAL, A. H., chief inspector, Chandler Motor Car Co., *Cleveland.*

FREDERICK, ROBERT GEORGE, student, Polytechnic Institute of Brooklyn, *Brooklyn, N. Y.*

GIBB, WILLIAM E., sales manager, Joseph Van Blerck Engine Corporation, *Plainfield, N. J.*

GILDEE, JOHN J., department head, Lowell Vocational School, *Lowell, Mass.*

GLEASON, R. M., assistant engineer, Yellow Cab Mfg. Co., *Chicago.*

GRUSS, RAYMOND L., president and general manager, Gruss Air Spring Co., *San Francisco.*

GUSTAFSON, WALTER A., student, Massachusetts Institute of Technology, *Cambridge, Mass.*

HAON, HARRY J., assistant division manager, E. I. duPont de Nemours & Co., *Newburgh, N. Y.*

HARRIS, SIDNEY G., student, Polytechnic Institute of Brooklyn, *Brooklyn, N. Y.*

HURLEY, FRANK EDWARD, JR., student, Polytechnic Institute of Brooklyn, *Brooklyn, N. Y.*

KATELEY, FRANCIS W., engineer, Traffic Motor Corporation, *St. Louis.*

KESTER, IVAN, draftsman Yellow Sleeve Valve Engine Works, Inc., *East Moline, Ill.*

KNIGHT, OSCAR A., district manager, Norton Co., *Worcester, Mass.*

KYRIAKIDES, HARRY B., student, Polytechnic Institute of Brooklyn, *Brooklyn, N. Y.*

LAMKER, HARRY G., foundry superintendent, Wright Aeronautical Corporation, *Paterson, N. J.*

LEATHERBEE, J. HOWARD, Pickering Governor Co., *Portland, Conn.*

LINDSAY, C. HARDIE, mechanical engineer, student, Tri-State College of Engineering, *Angola, Ind.*

LOMBARD, E. E., assistant military attaché, French Embassy, *City of Washington.*

LOVELAND, I. E., service manager, Remy Electric Co., *Anderson, Ind.*

MCDAVITT, W. F., tool designing, Shepard Arts Metal Co., *Detroit.*

MCKEE, L. Z., manager of sales, Canedy-Otto Mfg. Co., *Chicago Heights, Ill.*

MEAD-MORRISON MFG. CO., *East Boston, Mass.*

MICHELET, CHARLES J., JR., industrial engineer, Peoples Gas Light & Coke Co., *Chicago.*

MICHELSEN, HAROLD L., student, Polytechnic Institute of Brooklyn, *Brooklyn, N. Y.*

MITCHELL, LESLIE L., time study, Hudson Motor Car Co., *Detroit.*

NEUMANN, WILLIAM, student, Polytechnic Institute of Brooklyn, *Brooklyn, N. Y.*

OBERHOLLENZER, JOSEPH, student, Polytechnic Institute of Brooklyn, *Brooklyn, N. Y.*

OBERLE, A., research technologist, Universal Oil Products Co., *Chicago.*

OGDEN, CLARENCE E., president, treasurer and general manager, Automatic Electrical Devices Co., *Cincinnati.*

PEARSON, C. V., assistant secretary, Chicago Machine & Motor Co., *Chicago.*

READ, CLARENCE E., service manager, J. W. Robinson Co., *Lawrence, Mass.*

REED, CHARLES H., assistant sales manager, Forbes Varnish Co., *Cleveland.*

RINALDI, CHARLES J., student, Massachusetts Institute of Technology, *Cambridge, Mass.*

RODD, WILLIAM C., chief engineer, Saginaw Products Co., division of General Motors Corporation, *Saginaw, Mich.*

SEAVER, CHARLES H., salesman, Jones & Lamson Machine Co., *Springfield, Vt.*

SCHMIDT, E. P., chief draftsman, U. S. Ball Bearing Mfg. Co., *Chicago.*

SCHOLEY, WILLIAM A., vice-president, Cook Spring Co., *Ann Arbor, Mich.*

SCOTT, RALPH W., draftsman, Reo Motor Car Co., *Lansing, Mich.*

SMITH, R. D., chief engineer, Mar Tan Motor Mfg. Co., *Milwaukee.*

SPOONER, CLARENCE ROY, designer, Krikwen Axle Co., *Cleveland.*

STRAHS, EMANUEL H., student, Polytechnic Institute of Brooklyn, *Brooklyn, N. Y.*

SUMNER, LOUIS W., manager, Automotive Engineering Corporation, *Detroit.*

SWAN, HYLTON, manager of sales, Bakelite Corporation, *New York City.*

WARD, FRANK H., mechanical engineer, A. O. Smith Corporation, *Milwaukee.*

WELCH, PHILIP J., assistant tool engineer, Motor Wheel Corporation, *Lansing, Mich.*

WHITING, J. R. STURGE, sales manager, Edmonds Motors, *Thetford, England.*

Applicants *Qualified*

The following applicants have qualified for admission to the Society between Feb. 10, and March 10, 1924. The various grades of membership are indicated by (M) Member; (A) Associate Member; (J) Junior; (Aff) Affiliate; (S M) Service Member; (F M) Foreign Member; (E S) Enrolled Student.

ANDERSON, O. L. (A) layout draftsman, Rickenbacker Motor Co., *Detroit*, (mail) 605 Tennessee Avenue.

AXILROD, J. J. (A) vice-president and general manager, Keystone Forging Co., 347 Fifth Avenue, *New York City*.

BAILEY, ROBERT WILLIAM HARVEY (F M) technical production manager, Rolls-Royce, Ltd., Derby, England, (mail) The Firs, *Matlock, England*.

BEALL, A. L. (A) Automotive Electric Service Corporation, North Bergen, N. J., (mail) P. O. Box No. 124, *Ridgefield, N. J.*

BRYAN, HARRY F. (A) carbureter engineer, Ensign Carburetor Co., Los Angeles, (mail) 6200 St. Lawrence Street, *Chicago*.

COUSINS, E. A. (A) sales representative, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa., (mail) 9-255 General Motors Building, *Detroit*.

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HARRIS, SIDNEY G. (E S) student, Polytechnic Institute of Brooklyn, N. Y., (mail) 601 West 174th Street, *New York City*.

JACOBS, W. T. (M) chief draftsman, Stephens Motor Car Co., *Freeport, Ill.*, (mail) 1228 Lincoln Boulevard.

KAROW, HENRY ELMER (E S) student, Armour Institute of Technology, *Chicago*, (mail) 2234 South Sawyer Avenue.

LOCKWOOD, LOUIS H. (A) treasurer and chief engineer, Lockwood-Ash Motor Co., *Jackson, Mich.*, (mail) 730 Fifth Street.

LOTHROP, MARCUS (E S) student, Leland Stanford, Jr. University, *Stanford University, Cal.*

MONROE, V. W. (A) sales engineer, Prest-O-Lite Co., Inc., *Indianapolis*, (mail) Hotel Lincoln.

PILIBOSS, EDWARD D. (A) instructor of manual training, Central High School, *St. Louis*, (mail) 4008-A McPherson Avenue.

PIPER, J. C. (A) manager, Robert H. Hassler, Ltd., *Hamilton, Ont., Can.*, (mail) 405 Aberdeen Avenue.

POTTER, ERIC (F M) consulting engineer, Commerce Chambers, Parliament Street, *Nottingham, England*.

SEARIGHT, T. P. (F M) H. M. Hobson, Ltd., 29 Vauxhall Bridge Road, *London S. W. 1, England*.

SMITH, R. ROBERT (A) metallurgist, Robert H. Hassler, Inc., 1535 Naomi Street, *Indianapolis*.

USHIODA, SEIKICHI (F M) 2-2 Mita, Shiba-ku, *Tokyo, Japan*.

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WEBB, ROLAND R. (E S) student, University of Michigan, *Ann Arbor, Mich.*, (mail) 612 Church Street.

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